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(54) Optical fiber array and method of manufacturing

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Matrice de fibres optiques et son procédé de fabrication

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Description

TECHNICAL FIELD

[0001] The present invention relates to a parallel transmission module according to the preamble of claim 1 of the present invention. The parallel transmission module comprises an optical fiber array which optically couples with an LD (laser diode) array or a PD (photo-diode) array which are used in optical parallel transmission. The present invention further relates to a method of manufacturing a parallel transmission module.

BACKGROUND ART

[0002] In recent years, there are proposed optical interconnecting methods, in which a plurality of optical fiber lines are used to connect between apparatus such as large computers or mass-storage information exchange systems. The basic method of the optical interconnecting is, as shown in Fig. 1, connecting between apparatus 701 and 702 using an optical fiber line 703 which is made of a plurality of optical fibers and transmitting optical signals in parallel. A part of Fig. 1 is shown in Fig. 2. An optical module 704 for parallel transmission in the apparatus 701 and an optical module 705 for parallel transmission in the apparatus 702 are connected each other through multifiber optical connectors 706 and optical fiber lines 703.

[0003] As the multifiber optical connector 706, for example, there is a three-part optical fiber connector disclosed in EP 0 458 608. Said optical fiber connector comprises two optical fiber connector parts and, adapted to optically interconnect the two optical fiber connector end parts, a mating adaptor. Encapsulated in a plug of the optical fiber connector end part is a moulded array connector in an exposed end face of which are exposed the end faces of a plurality of optical fibers optically connected to the optical fibers of an optical cable.

[0004] As a further example for the multifiber optical connector 706 there is an optical fiber array having a structure which optical fibers are held by V-shaped grooves formed by etching silicon (hereinafter simply called Si), (Journal of Lightwave Technology Vol. Lt-3 No. 5, p. 1159, issued in October, 1985). A process for producing such an optical connector having V-shaped grooves is also disclosed in EP 0 405 620 A2. Further, there is an optical fiber array having a structure which optical fibers are put between two L-shaped magnets, which array is disclosed in Japanese Patent Laid-open No. 4-86802 (86802/1992) has been known.

[0005] However, the aligned optical fiber array with an LD array or a PD array is fixed by using solder bonding or a YAG laser, its heat is also transferred to the optical fiber array, which heats up the optical fiber array to 200°C or above. Consequently, the problems of distortion appearing in micro order depending on the state of assembly, degrade of the coupling part, gas generation

from adhesive around the optical fiber array, degrade of characteristics due to dew, and others arise.

[0006] As shown in Fig. 3, in the optical module 704, a fiber ribbon 703a is continuously formed and the multifiber optical connector 706 is placed at one end of the fiber ribbon 703a, which is what is called a pigtail type. It is also known that the fiber ribbon 703a and the multifiber optical connector 706 are placed at both ends of a silica waveguide 707 (e.g., an optical branching filter, an optical multiplexer, or an optical switch), which is what is called a jumper type.

[0007] However, the parallel optical transmission module, especially the pigtail type is difficult to handle the ribbon part of the optical fiber ribbon in each manufacturing process. A coating part of the optical fiber ribbon is made of resin which is inferior in heat resistance and which is difficult to handle when the module is fixed with solder or cleaned. For the jumper type, there are also disadvantages that the ribbon part of the optical fiber ribbon is complicated to handle, and that if it is stored in a small area, bend radius of the optical fiber needs 30 mm or above, which makes a space for mounting larger.

[0008] On the other hand, as shown in Figs. 1 and 2, in the case of optically coupling the parallel optical transmission module with the external apparatus, the parallel optical transmission module is coupled with the optical connector 706 which ties to the external apparatus through the fiber ribbon 703a and the multifiber optical connector 706, but in this coupling, since the coupling is made at one end of fiber which is wired from the substrate to outside, wiring is often distorted, and when not coupling, the connector at one side is hang down. Consequently, it is inconvenient to handle the fiber ribbon and the coupling end face of the fiber may be damaged.

[0009] It is an object of the present invention to provide a parallel transmission module comprising an optical fiber array with sufficiently high airtightness and a method for manufacturing the parallel transmission module.

DISCLOSURE OF THE INVENTION

[0010] A parallel transmission module of the present invention transmits a plurality of optical signals in parallel. The parallel transmission module comprises a module body comprising a plurality of optical transmission systems for transmitting the optical signals separately, an optical fiber array which is provided at one end of the optical transmission systems provided in the module body and fixed at the module body and which comprises a plurality of optical fibers for optically coupling the optical transmission systems individually, and guiding means for guiding another optical connector to couple with an optical coupling end face of the optical fiber array. The optical coupling end face is located at the opposite side to the end face optically coupled with the optical transmission systems. Said guiding means is one

of a guide pin for positioning said other optical connector to be coupled with said optical coupling end face of said optical fiber array and the guide groove for receiving a guide pin provided at said other optical connector to be coupled with said optical coupling end face of said optical fiber array. A flange member is put at the peripheries of said first and second plate. The optical fiber array comprises a first plate comprising a plurality of positioning grooves for positioning said optical fibers. The optical fiber array further comprises a second plate for pressing each said optical fiber provided in each said positioning groove on said first plate into said positioning grooves. Support plates are provided at both sides in a cross direction of said first plate so as to protrude from both sides to support said guide pin. Said optical fibers, said first and second plates for holding said optical fibers, and said flange member are fixed together. Solder or low melting point glass is inserted into the space between the lower and upper plate and between the flange and the metal sleeve so that the solder or low melting point glass is filled in the space in substantially an entire cross section in a plane perpendicular to a longitudinal direction of said optical fiber. Said optical fibers are fixed between said first and second plate airtightly by the solder or low melting point glass, as well as said metal sleeve and the flange.

[0011] A method of manufacturing a parallel transmission module according to the present invention is set forth in claim 19.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Fig. 1 is a view showing a plurality of optical fiber lines being used to connect information apparatus such as large computers.

[0013] Fig. 2 is a plane view showing a part of Fig. 1.

[0014] Fig. 3 is a view showing a conventional pigtail type parallel transmission module.

[0015] Fig. 4 is a view showing a conventional jumper type parallel transmission module.

[0016] Fig. 5 is a perspective and exploded view showing an optical fiber array according to the embodiment.

[0017] Fig. 6 is a view showing the completion of an optical fiber array of Fig. 5.

[0018] Fig. 7 is a vertical cross sectional view showing an optical fiber array.

[0019] Fig. 8 is a cross sectional view along the lines A-A' in Fig. 7.

[0020] Fig. 9 is a schematic view showing a state of an optical fiber array fixed to an LD module.

[0021] Fig. 10A and Fig. 10B are perspective views showing a configuration of a sleeve.

[0022] Fig. 11 is a perspective view showing an end of an optical fiber array.

[0023] Fig. 12A-Fig. 12C are views showing a method of processing an Si wafer constituting an upper and lower plates.

[0024] Fig. 13 is a perspective view showing an end of another optical fiber array.

[0025] Fig. 14A-Fig. 14D are views showing an example of a configuration of V-shaped grooves in each anode-coupled optical fiber array.

[0026] Fig. 15A is a plane view showing a refractive index distribution type optical fiber array and Fig. 15B is its sectional view.

[0027] Fig. 16A is a plane view showing a configuration of an optical fiber array, Fig. 16B is a vertical cross-sectional view showing an internal configuration of an optical fiber array, and Fig. 16C is a vertical cross-sectional view showing another internal configuration of an optical fiber array.

[0028] Fig. 17 is a view showing a configuration of an enlarged end of an optical fiber array.

[0029] Fig. 18A is a vertical cross-sectional view showing a hermetically sealed optical fiber array, Fig. 18B is a view showing its end face, and Fig. 18C is a view showing a method of filling solder from an end of an optical fiber array while ultrasonic oscillation is applied.

[0030] Fig. 19A is a view showing a state that a protuberance is formed by soldering at an end of an optical fiber array, and Fig. 19B is a view showing a state that an end face is polished to be a plane.

[0031] Fig. 20 is a view showing a state that an optical fiber array is bonded to a parallel transmission module, and Fig. 21 is a view showing its conventional state.

[0032] Fig. 22A is a plane view showing another configuration of an optical fiber array, Fig. 22B is its vertical sectional view, and Fig. 22C is a view showing its end face.

[0033] Fig. 23A is a view showing a state that an end of an optical fiber array is soaked into a solder tub, and Fig. 23B is a view showing a condition of solder adhesion in a case of a step provided on a sleeve.

[0034] Fig. 24A is a plane view showing one example of a configuration of an optical fiber array, and Fig. 24B is its vertical sectional view, and Fig. 24C is a view showing an end face of an optical fiber.

[0035] Fig. 25A is a vertical sectional view showing a basic configuration of a parallel transmission module, and Fig. 25B is a side view showing a state that a parallel transmission module is coupled with an optical fiber array.

[0036] Fig. 26 is a perspective view showing an optical fiber array having guide-pin grooves.

[0037] Fig. 27A is a plane view showing a state that a parallel transmission module is constituted with a waveguide substrate, and Fig. 27B is a side view showing a state that the parallel transmission module is coupled.

[0038] Fig. 28 is a plane view showing a state that an optical fiber array is coupled with a silica waveguide substrate using a guide pin.

[0039] Fig. 29A-Fig. 29C are views showing a configuration of guide pin grooves being shield.

[0040] Fig. 30A is a plane view showing a state that an optical fiber array and a parallel transmission module are fixed by a pressing member, and Fig. 30B is its side view.

[0041] Fig. 31 is a perspective view showing an optical fiber array with a metal sleeve fixed, and Fig. 32 is a view showing an enlarged part of one end of an optical fiber array.

[0042] Fig. 33 is a perspective view showing a configuration of optical fibers fixed by pressing an independent upper plate, and Fig. 34 is a perspective view showing an example of its modification.

[0043] Fig. 35A-Fig. 35D are views showing a configuration of various kinds of MFD.

[0044] Fig. 36A and Fig. 36B are views showing a configuration of preventing reflection at a coupling end face.

[0045] Fig. 37 is a plane view showing a configuration of an optical fiber array using an optical fiber having an enlarged MFD.

[0046] Fig. 38-Fig. 46 are views showing a process of manufacturing a parallel transmission module in order.

[0047] Fig. 47A is a top view showing a lower plate and a support plate, and Fig. 47B is its side view, and Fig. 47C and Fig. 47D are views showing its front end and a side view showing its rear end, respectively.

[0048] Fig. 48A is a top view showing a state that a rear end of an optical fiber array is soaked in a solder tub to seal a flange and to fill solder into its front end, Fig. 48B is its side view, Fig. 48C is a side view of its front end, and Fig. 48D is a side view showing its rear end.

[0049] Fig. 49 is an enlarged view of Fig. 48D.

[0050] Fig. 50A is a top view showing a state that both ends are polished after Fig. 48, Fig. 50B is its side view, Fig. 50C is a side view showing its front end, and Fig. 50D is a side view showing its rear end.

[0051] Fig. 51A is a top view showing a state that a protective sleeve is put at an optical fiber array of Fig. 50A, Fig. 51B is its side view, Fig. 51C is a side view showing its front end, Fig. 51D is a side view showing its rear end, and Fig. 51E is a vertical sectional view showing a state that a guide pin inserted in a guide-pin groove is pressed by a pressing member such as a metal spring.

[0052] Fig. 52A is a top view showing another embodiment of a lower plate and a support plate, Fig. 52B is its side view, Fig. 52C is a side view showing its front end, and Fig. 52D is a side view showing its rear end.

[0053] Fig. 53A is a top view showing a state that a lower plate and a support plate of Fig. 52A are fixed by fixing agent injected from one end, Fig. 53B is its side view, and Fig. 53C is its sectional view showing its end.

[0054] Fig. 54A is a top view showing a state that one end of a module is polished, and Fig. 54B is its side view, and Fig. 54C is a sectional view showing its end.

[0055] Fig. 55A is a top view showing a state that a rear end of a module of Fig. 54A is fixed by solder after

guide pins and a protective sleeve are installed, Fig. 55B is its side view, and Fig. 55C is a sectional view showing its front end.

[0056] Fig. 56A is a top view showing a completed optical fiber array after polishing its rear end in succession Fig. 55A, Fig. 56B is its side view, and Fig. 56C is a sectional view showing its front end.

[0057] Fig. 57 is a schematic view showing a state that a wall is provided on a lower plate, and Fig. 58 is a schematic view showing another configuration of a wall.

[0058] Fig. 59 is a schematic view showing a state that a guide pin is supported by a clasper.

[0059] Fig. 60 is a side view showing a modified guide pin.

[0060] Fig. 61 is a top view showing one aspect of a coupling face of an external optical connector and a coupling face inside a module.

[0061] Fig. 62A and Fig. 62B are schematic views showing a state that a MFD of an optical fiber is partially or totally converted.

[0062] Fig. 63 is a perspective view showing housing structure.

[0063] Fig. 64 is a plane view showing each housing before coupling.

[0064] Fig. 65 and Fig. 66 are views showing a coupling mechanism in order.

[0065] Fig. 67 is a vertical sectional view showing a releasing mechanism.

[0066] Fig. 68 is a schematic and perspective view showing a shield plate provided in a housing.

[0067] Fig. 69 is a plane view showing each housing before coupling.

[0068] Fig. 70A-Fig. 70C are views showing a procedure of releasing a lock between housings in order.

[0069] Fig. 71 is a perspective view showing a configuration of an optical fiber array.

[0070] Fig. 72 is a schematic view showing a configuration of a parallel transmission module stored in a housing.

[0071] Fig. 73 is a block diagram of a parallel transmission module comprising modules for emitting light and for receiving light.

[0072] Fig. 74 is a perspective view showing an optical fiber array provided in a parallel transmission module of Fig. 73.

[0073] Fig. 75 is a schematic view showing an enlarged end face of an optical fiber array.

[0074] Fig. 76A-Fig. 76D are views showing an example of arrangement of light emitting devices and light receiving devices.

[0075] Fig. 77 is a view showing an end face of an optical fiber array corresponding to two-dimensional arrangement.

[0076] Fig. 78A and Fig. 78B are views showing a MFD enlarged conversion optical fiber or a MFD reduced conversion optical fiber.

BEST MODE FOR CARRYING OUT THE INVENTION

[0077] The embodiments of the present invention will be explained with reference to the drawings. Note that optical fiber arrays or others shown in the following embodiments are mainly used in an optical interconnection which couples between information apparatus such as large computers or mass-storage information exchange systems (see Fig. 1 and Fig. 2).

Embodiment 1

[0078] An optical fiber array according to the present embodiment is shown in Fig. 5. The optical fiber array comprises a lower plate 3a and an upper plate 3b which are made of silicon wafers, and a plurality of optical fibers 1 are stored between the lower plate 3a and the upper plate 3b. The optical fibers 1 extend from a ribbon part (coated region) 7 of a multi-optical fiber ribbon. The lower plate 3a has a plurality of V-shaped grooves 4 for storing the optical fibers 1 in position, and every optical fiber 1 to be placed in the V-shaped groove 4 is pushed inside the V-shaped groove 4 by the upper plate 3b. A metal sleeve 8 is put around the lower plate 3a and the upper plate 3b which sandwich the plurality of optical fibers 1 (Fig. 6). Note that the sleeve 8 comprises a window part 5, the function of which will be described later.

[0079] The optical fiber array in a fixed state is shown in Fig. 7. The multi-optical fiber ribbon is fixed to the lower and upper plates 3a and 3b to plug heat resistant adhesive 10 as far as the vicinity of the boundary portion between the coated ribbon part 7 and the optical fibers 1. Next, the remaining parts of the optical fibers 1 from the boundary portion to the end are fixed to the lower and upper plates 3a and 3b by solder 6. With thus fixed optical fiber array by the solder 6, the sufficient airtightness is ensured. If the solder 6 comes in contact with the ribbon part 7 which is a coated part, the coating of the ribbon part 7 melts and a large amount of gas generates. Therefore, it is preferable that the vicinity of the boundary portion between the ribbon part 7 and the optical fibers 1 is protected by the adhesive 10 and thereafter the glass part of the optical fiber 1 is fixed with the solder 6.

[0080] The solder 6 is fed from one ends of the optical fibers while ultrasonic oscillation is applied. Thereafter, if the adhesive is filled near the ribbon part 7, air is accumulated inside because the inside is sealed, which may result in insufficient filling. Then, a window part (through window) 5 is provided at the sleeve 8 to be an air vent when the adhesive is filled. The window part 5 is provided at a position where the optical fibers 1 are exposed, whereby a boarder between the solder 6 and the adhesive 10 is formed at the glass part of the optical fibers 1. Further, the effect of providing such a window part 5 is preventing the solder from rising since the gap at a boarder portion is expanded. Providing a slight gap between the lower plate 3a and the upper plate 3b

makes the solder 6 flow easier.

[0081] Since the optical fiber 1 receives the heat of 200 °C or above when fixed with solder, crack rapidly develops on a surface of the optical fiber and the optical fiber is easily broken. Then, if an optical fiber which is coated by carbon is used, the development of crack can be suppressed.

[0082] Further, solder which is suitable for bonding glass which forms an optical fiber is necessary. For this sort of solder, the additive agent such as Zn, Sb, Al, Ti, Si, or Cu is added to general Pb-Sn alloy, so that the effective bonding through the medium of oxygen can be made possible.

[0083] In this case, a compounding ratio of the additive agent to solder is 0.01-5 weight per 100 weight of solder, and more preferably 0.05-1.5 weight. As suitable solder for use, for example, "Serasoruza W" (manufactured by Asahi Garasu Inc.) is preferable. If the compounding ratio of the additive agent is less than 0.01 weight, the bond strength to the glass is insufficient, and if it exceeds 5 weight, the characteristics of solder itself are lost and the junction strength is not improved.

[0084] Thus constructed optical fiber array is fixed to, e.g., an LD module with solder. In the case of the complete hermetic sealing, how to seal a gap between a sleeve plate and optical fibers is important.

[0085] Then, as shown in Fig. 7 and Fig. 8, when it is designed so that the solder 6 injected from one ends of the optical fibers 1 is circulated to this gap, the cross section along the lines A-A' is completely and hermetically sealed. In the case of fixing the optical fiber array to the LD module (LD), as shown in Fig. 9, the periphery of the sleeve 8 is fixed to the LD module with the solder 6 in an airtightness state. Thus, the whole body can be hermetically sealed.

[0086] The adhesive 10 also needs to have heat resistance. The adhesive 10 that a weight loss is more than 1 % when heated at 260 °C for 10 seconds, may be adhered to an LD lens in the module, which may cause the degradation. Therefore, the adhesive which has a weight loss of 1 % or below when heated at 260 °C for 10 seconds, e.g., epoxy adhesive is desirable.

[0087] The structure of the optical fiber array is basically classified into a sandwich type shown in Fig. 11 and an anode coupling type shown in Fig. 13.

[0088] The sandwich type has structure that the optical fibers 1 are sandwiched between the lower and upper plates 3a and 3c having V-shaped grooves as shown in Fig. 11. In this case, at least one side of the inner surface of the V-shaped grooves, which grooves hold the optical fibers 1, may preferably have a curved surface having a radius R of curvature (hereinafter called R-surface). In this case, the same effect can be expected whether both sides of the inner surface of the V-shaped grooves have the R-surface, or one side of the inner surface of the V-shaped grooves has the R-surface and the other side thereof has the flat surface.

[0089] The sleeve 8 can be formed as a square sleeve

type elastic sleeve 9a or a press type elastic sleeve 9b as shown in Fig. 10A and Fig. 10B, respectively. Note that it is preferable that the sleeves 8, 9a and 9b are made of amber alloy. Thus, pressing the optical fiber module externally with the sleeves 9a and 9b which are made of amber alloy makes the assembly of the optical fibers easier.

[0090] The amber alloy is Ni-Fe alloy. For example, for 42% Ni, a coefficient of thermal expansion is small: 4.4×10^{-6} (30-300°C), and for 36% Ni, a coefficient of thermal expansion can be decreased to about 2.0×10^{-6} , so that it has advantage that the optical fiber array is hardly transformed when it is fixed to the optical module even though the heat is applied to.

[0091] Furthermore, as shown in Fig. 12A-Fig. 12C, the silicon wafer 3 is ground using a diamond blade to form the V-shaped grooves 4 having bases of R-surfaces of 5 μm or above.

[0092] Consequently, "crack" which is caused by the stress concentration and which frequently occurs in the V-shaped grooves which are formed by the conventional etching can be prevented. Processing a silicon wafer 3 to form V-shaped grooves 4 using a V-shaped diamond blade 11 is shown in Fig. 12B. After the V-shaped grooves 4 are formed, as shown in Fig. 12C, the silicon wafer 3 is divided into two, and their surfaces on which the V-shaped grooves are formed are put together to use as an lower and upper plates 3a and 3c. The optical fibers can be positioned with equal spacing with high precision using thus constructed lower and upper plates 3a and 3c.

[0093] The appearance of the anode bonding type optical fiber array is shown in Fig. 13.

[0094] The anode coupling is to bond a lower plate 3a made of a silicon wafer with an upper plate 3b made of glass such as Pyrex glass or aminosilicate glass or made of glass deposited Si by putting the lower and upper plates together, heating at about 400 °C and applying 1000V. This bonding can integrate the lower and upper plates 3a and 3b entirely, so that hermetic sealing at side surface can be perfect.

[0095] Na ions in the upper plate 3b of glass are transferred in electric field, and Si-O bonding generates. Si and Si can be bonded at low voltage of 50-60V if one of Si plates on which thin glass is vapor-deposited is used. In this case, the optical fibers 1 can be inserted after the lower and upper plates 3a and 3b are anode-coupled, which improves the work efficiency. Various structures of V-shaped grooves of the anode coupling type optical fiber array are illustrated in Figs. 14A-14D.

[0096] The observation of the solder filling condition can be made easier since the upper plate 3b of glass is transparent. Moreover, the confirmation of positions of SM (single mode) optical fibers 16 with GI (graded index) optical fibers 15 shown in Fig. 15A and Fig. 15b can also be made easier.

[0097] Ni-Fe amber alloy is preferably used in a part of the fixing region (positioning region) for the optical

fiber ribbon part as well as the array plate which forms the guide grooves for the optical fibers. If Ni-Fe amber alloy is not used in a part of the fixing region for the optical fiber ribbon part, it is not good because of thermal transformation and distortion. Further, an amber alloy plate, and the upper and lower plates are preferably formed to sandwich the ribbon part 7 of the optical fiber line. In this case, it is superior in rigidity.

[0098] Further, it is good in reliability when amber alloy is of square sleeve shape and a part of the upper and lower plates which hold the optical fibers is inserted into the amber alloy.

[0099] Conventionally, because a SELFOC lens (trade name: manufactured by Nippon Itagarasu company) was used for condensing light when the optical fiber array was aligned and coupled to an LD array module, two stages of alignment, which are alignment and fixation of the LD with the SELFOC lens and alignment and fixation of the SELFOC lens with the optical fiber array, were performed. Consequently, work was complicated, which raised cost, and connection loss was increased. In the present embodiment, as shown in Fig. 15A and Fig. 15B, when SM optical fibers 16 to which GI optical fibers 15 having a certain length is fused are used in the optical fiber array, the optical processing in accordance with the purpose such as conversion of NA (numerical aperture) or an optical collimating system can be built-in the optical fiber array.

[0100] The GI optical fibers 15 and the SM optical fibers 16 are self-aligned when they are coupled each other. The outer diameter is preferably equal but the difference of 20-30% will not be a problem because the self-alignment of glass acts upon the difference.

[0101] It is preferable to use carbon coated optical fibers in a view of reliability. In this case, the coupled parts of the GI optical fibers 15 and the SM optical fibers 16 can easily be distinguished by removing carbon with heat when coupled, and automatic cutting and polishing system in which the image processing is used can be made easier.

[0102] Δn or a core diameter of the GI optical fiber 16 is set in accordance with an object. The core material may also be used up to the outer circumference.

[0103] High precision-positioning is easily performed if a recess part is formed in a guide groove (enlarged V-shaped groove corresponding to a coupled part) 17 as shown in Fig. 15B since the outer diameter of the coupled part is frequently varied in submicron order. The guide groove 17 may be expanded over the SM optical fiber 16. Only the GI optical fiber 15 may be precisely positioned.

[0104] It should be noted that optical fiber positioning is also carried in a multifiber optical connector or others but this embodiment is to achieve the permanent fixation and the hermetic sealing in an alignment state, which is completely different from the conventional multifiber optical connector.

Working example

[0105] A silicon wafer was processed to form V-shaped grooves with a diamond blade, and the sandwich type and the anode coupling type array plates were formed. The V-shaped grooves were processed with the eccentricity of $\pm 0.3 \mu\text{m}$.

[0106] A housing for each type was formed using amber alloy, and optical fibers 1 were fixed at one ends about 4mm with solder which was Sb-Pb alloy containing Zn, Sb, Al, Ti, or others, and a ribbon part 7 was fixed by injecting the epoxy heat-resistant adhesive (amount of gas generation was 0.1% when heated at 260°C for 10 seconds) from a window part 5 (see Fig. 11).

[0107] The optical fibers were 18-optical fibers which were coated by carbon, and a spacing between the fibers was $250 \mu\text{m}$. The optical fibers which had a $125 \pm 0.3 \mu\text{m}$ outer diameter and the eccentricity of core within $0.3 \mu\text{m}$ were used. After assembled, referring the first fiber and the 18th fiber as references, the eccentricity of the other optical fibers was measured. The eccentricity was suppressed all within $1.0 \mu\text{m}$: the average of $0.4 \mu\text{m}$ and the maximum of $0.8 \mu\text{m}$.

[0108] For the anode-bonding type, a silicon wafer and a Pyrex glass were coupled at 400°C and 1000V. For the sandwich type, a base R of the V-shaped groove was processed to $20 \mu\text{m}$, so that no array plates were broken in an impact test or handling.

[0109] The following advantages can be achieved owing to such structure of the optical fiber array.

[0110] First, V-shaped grooves in which R-surfaces are formed are used to prevent a silicon wafer from cracking, and to achieve an optical fiber array which can be mass-produced. Further, hermetic sealing can be achieved since solder is used in fixation. Furthermore, thermal transformation can be reduced by combining amber alloy. An optical fiber array with a built-in lens is formed, so that a process of aligning an optical fiber array with a conventional LD module can be completed once. Carbon coated fibers are used to obtain an optical fiber array with high reliability. Owing to an anode-coupling type optical fiber array, side hermetic sealing is ensured and the structure which is hardly transformed by heat can be achieved. A sandwich array is pressed by an amber alloy housing, so that the installation of the optical fibers is made easier.

Embodiment 2

[0111] Fig. 16A-Fig. 16C show basic structure of a sandwich type optical fiber array according to the present embodiment. The same components as the embodiment 1 are represented by the same reference numerals.

[0112] In Fig. 16A-Fig. 16C, an optical fibers 1 are clamped between an lower and upper plates 3a and 3b, which is a shape of sandwich. The optical fibers 1 and the lower and upper plates 3a and 3b are sealed to the

inside of a metal sleeve 8 by solder.

[0113] The reference numeral 5 is a window part (opening) provided at a proper position of the sleeve 8, and the upper plate 3b placed inside can be pressed with a clamp member such as a plate spring through the window part 5.

[0114] One end face of the metal sleeve 8 at an optical coupling end face of the optical fiber array is polished so as to be the same plane as the end face of the optical fiber array. With such structure, the polished face f of the sleeve 8 is suitable for a confronting face when the optical fiber array is aligned and fixed to other parts of the parallel transmission optical module, e.g., an LD array or a lens array.

[0115] As shown in an enlarged version of Fig. 17, if one end face 3d of the lower and upper plates 3a and 3b are positioned within the polished face, solder 6 is filled at the end of the sleeve 8, which makes the hermetic sealing perfect.

[0116] In this case, as shown in Fig. 17, a gap between the polished face f and the lower and upper plates 3a and 3b is hermetically sealed by an airtight sealing part 20 such as solder or low melting point glass, and at the same time, the solder 6 also seals a gap between the lower and upper plates 3a and 3b, and the sleeve 8.

[0117] Distance between the polished face f and the end faces 3d of the upper and lower plates, that is, an amount of pulling-in only requires a gap for filling solder or adhesive, and preferably it does not exceed 1 mm in order to maintain the accuracy of optical fiber disposition.

[0118] It is preferable that at least one of the lower and upper plates 3a and 3b which are optical fiber positioning members has V-shaped grooves.

[0119] The upper plate 3b may be made of a transparent member whereby the observation of the solder filling condition can be made easier. Moreover, the confirmation of the position of the optical fibers 1 can be made easier.

[0120] The lower and upper plates 3a and 3b may be formed by bonding two array plates which have V-shaped grooves, and guide holes (not shown) are formed in the lower and upper plates 3a and 3b to insert and position the optical fibers 1. For the structure of the V-shaped grooves, the V-shaped grooves preferably have bases of R-surfaces as described in the embodiment 1, and more particularly, R-surface preferably has a radius of curvature of $5 \mu\text{m}$ or above.

[0121] In this embodiment, the optical fiber array may be constructed so that a plane spring, e.g., made of amber alloy presses optical fibers through the window part 5 provided in the sleeve 8. Consequently, the assembly of the optical fiber array is made even easier.

[0122] Fig. 18A-Fig. 18C are schematic views showing a method of hermetically sealing optical fibers with solder. It is preferable that solder 6 is only used to fix the glass parts of the optical fibers 1 because the solder 6 melts the ribbon part 7 which is the coated optical fib-

ers 1 and the large amount of gas generates.

[0123] As shown in Fig. 18C, it is preferable that the solder 6 is fed from the ends of the optical fibers 1 while ultrasonic oscillation 21 is applied. In particular, ultrasonic oscillation 21 by an ultrasonic oscillator (not shown) is applied to the solder 6 in a solder bath 22, which is heated to temperature suitable for sealing (that is, temperature at which the solder is viscous so as to rise in a gap between the optical fibers 1 and the lower and upper plates 3a and 3b). It is desirable that an end of an optical fiber array F is inserted in the solder bath 22 to circulate the solder into a gap.

[0124] Further, it is desirable that as shown in Fig. 18B, a gap is formed between the optical fiber array F and the sleeve 8 to circulate the solder 6 sufficiently for perfect hermetic sealing when the optical fiber array F is connected with the sleeve 8 by solder.

[0125] In order to prevent an optical fiber surface from cracking or breaking, the optical fiber 1 is preferably coated by carbon or others in advance.

[0126] For the solder material, it is preferable that the additive agent such as Zn, Sb, Al, Ti, Si or Cu is added to general Pb-Sn alloy.

[0127] For the heat resistant adhesive 10, the adhesive in which an amount of gas generation is 1% or less of weight when heated at 260 °C for 10 seconds is desirable, e.g., epoxy adhesive.

[0128] Material of the lower and upper plates 3a and 3b is preferably silicon, glass or ceramic, or combination of these.

[0129] Fig. 19A and Fig. 19B are schematic views showing a method of forming an optical coupling end face with other optical module at one end face of an optical fiber array F.

[0130] As shown in Fig. 19A, a protuberance 23 is formed by applying solder or adhesive. Thereafter, as shown in Fig. 19B, one end face of the protuberance 23 is polished so that the end face of the sleeve 8 and the end faces of the optical fibers 1 are the same plane. In result, solder or adhesive is exposed at the end face after polishing, which constructs airtight structure.

[0131] Fig. 20 is a schematic view showing a method of bonding an optical fiber array F with a parallel optical transmission module M. The optical fiber array F needs to be bonded with the parallel optical transmission module M with a certain gap (Z). In this case, a case 31 is provided at the exterior of the optical module M, and the optical fiber array F is bonded to this case 31. In particular, it is preferable that one end face of the case 31 and the optical fiber array F are bonded at a part denoted by the reference numeral 34 with solder or YAG laser welding. In this case, in Fig. 20, the end face of the case 31 and the end face of the optical fiber array F make a reference plane. Note that in Fig. 20, the reference numerals 32 and 33 denote a lens array and an LD array, respectively.

[0132] On the other hand, Fig. 21 shows a conventional method in which an optical fiber array F is inserted

into one end face of the case 31 and sealed. In this case, the XYZ alignment is required.

[0133] Note that the metal sleeve 8 is preferably made of amber alloy.

Working example

[0134] A silicon wafer was processed to form V-shaped grooves with a diamond blade, and a sandwich type array plate was formed. The V-shaped grooves were processed with the eccentricity of $\pm 0.3 \mu\text{m}$.

[0135] A sleeve 8 was formed using amber alloy, and optical fibers 1 were fixed with solder which was Sb-Pb alloy containing Zn, Sb, Al, Ti, or others at one ends about 4mm, and the other parts of the optical fibers were fixed with epoxy heat-resistant adhesive (an amount of gas generation was 0.1% when heated at 260 °C x 10 seconds) by injecting from a window part 5 (see Fig. 16B). The fixed optical fiber line was 18-optical fibers which were coated by carbon, and a spacing between the fibers was 250 μm . The optical fibers which had a $125 \pm 0.3 \mu\text{m}$ outer diameter and the eccentricity of core within 0.3 μm were used. After assembled, referring the first fiber and the 18th fiber as references, the eccentricity of the other optical fibers was measured. The eccentricity was suppressed all within 1.0 μm : the average of 0.4 μm and the maximum of 0.8 μm .

[0136] Next, as shown in Fig. 19A, solder was applied to one end face of the optical fiber array F to form a protuberance 23. Thereafter, the end face of the protuberance 23 was polished so that the end face of the optical fiber array F and the end face of the sleeve 8 are the same plane, and then was connected to the optical part of the optical module.

[0137] Further, a case 31 which protected an optical module M and the sleeve 8 which coated the optical fiber array F were welded by a YAG laser to be integrated. In this case, the sleeve 8 was bonded with the case 31 with a certain gap Z (20 μm) to the optical parts such as a lens array 32 constituting the optical module.

[0138] An advantage of polishing the end face of the sleeve 8 and the end face of the optical fiber array F at the same time is not requiring the parallel transfer in a longitudinal direction and the alignment in a rotating direction of two axes perpendicularly intersecting in a longitudinal direction and only requiring the alignment in X and Y directions and in X and Y planes. Further, the end faces are easily sealed with solder.

Embodiment 3

[0139] Another embodiment is shown in Fig. 22A-Fig. 22C. Optical fibers 1 are inserted into V-shaped grooves 37 formed in an lower and upper plates 3a and 3b, and the optical fibers 1 are clamped by the lower and upper plates 3a and 3b.

[0140] The optical fiber array F soaked in a solder bath 22 is shown in Fig. 23A. As shown in Fig. 23A, with

the fixed optical fibers, the optical fiber array F is soaked in the solder bath 22 up to the end of a sleeve 8, which easily seals the inside of the sleeve 8 entirely when the optical fiber array F is installed.

[0141] In particular, a distance between the end face of the optical fiber array F and the end of the sleeve 8 is preferably within 2mm, which is preferred from an aspect of work efficiency.

[0142] In Fig. 23A, the sleeve 8 is located slightly behind the end face of the optical fiber array F and the optical fiber array F can be soaked up to the sleeve 8 and sealed, so that the sealing is ensured and is made easier. The condition of solder adhesion in a case of a step 8a being provided on the sleeve 8 is shown in Fig. 23B.

[0143] Fig. 24A-Fig. 24C show structure of a sleeve 8 with a step 8a provided.

[0144] In Fig. 24A-Fig. 24C, structure of an optical fiber array, in which a sleeve 8 having a step 8a projecting 1mm or above, or preferably 2mm or above behind from the end of the sleeve 8 is provided outside the lower and upper plates 3a and 3b, is shown.

[0145] Owing to such structure, solder 6 adheres up to a part shown in Fig. 23B. Consequently, it has an advantage that there is no influence of solder near the end face when the optical fiber array is coupled to an optical device after the optical fiber array is set.

[0146] Material of the lower and upper plates 3a and 3b is preferably silicon, glass or ceramic, or combination of these.

[0147] In this case, it is preferable that a window part 5 is also provided in the sleeve 8. The window part 5 is effective when the upper plate 3b or the lower plate 3a is pressed with a clamp member (not shown) such as a plane spring made of amber alloy.

[0148] The sleeve 8 serves as both a laser welding flange for sealing an optical fiber array and a flange for solder fixation, but the flange may be provided to another body other than the metal sleeve 8.

[0149] The preferred amber alloy for the sleeve 8 is Ni-Fe alloy. It has advantages that a coefficient of thermal expansion is low, and that it is hardly transformed even though the heat is applied when the optical fiber array is fixed to the optical module.

[0150] It is preferable that only glass parts of the optical fibers are fixed with solder and that coated parts of the optical fibers are fixed with heat resistant adhesive since the coating of the optical fibers melts on contact with solder and generates a large quantity of gas.

[0151] Solder is easily injected if it is fed from the end of the optical fiber while ultrasonic oscillation is applied when the optical fiber is soaked in the solder bath, which is preferred from an aspect of airtightness.

[0152] Further, it is desirable that a gap is formed between the optical fiber array and the sleeve to circulate the solder sufficiently for perfect hermetic sealing when the optical fiber array and the sleeve are bonded with solder.

[0153] The optical fibers 1 are preferably coated by carbon or others in advance in order to prevent an optical fiber surface from cracking or breaking.

[0154] For the solder material, it is preferable that additive agent such as Zn, Sb, Al, Ti, Si or Cu is added to general Pb-Su alloy.

[0155] One end face of the optical fiber needs to be polished. In result, the solder is exposed and the airtight structure is achieved.

[0156] When the optical fiber array F is coupled to an optical device, an optical connector or others, a case may be provided to an exterior of the optical module. In particular, the end face of the module array case and the optical fiber array can be coupled by solder fixation or YAG laser welding.

[0157] As described above, the sleeve 8 which is provided at the periphery of the optical fiber array is located slightly behind the end face of the optical fiber array, so that it can be easily soaked in the solder tab, and the airtight sealing can be perfect. Further, it is easily polished since the end face of the optical fiber array projects from the sleeve 8. Furthermore, it is another advantage that there is no influence of solder adhered near the end face of the optical array since the sleeve 8 has the step 8a.

Embodiment 4

[0158] The parallel transmission module according to the present embodiment will be explained with reference to the accompanying drawings.

[0159] There are shown a parallel transmission module comprising a light emitting device, a light receiving device, an optical fiber array and an external optical connector in Fig. 25A and Fig. 25B. The parallel transmission module mainly comprises a module body 51 and an optical fiber array 40 fixed at the module body 51.

[0160] The module body 51 comprises a laser diode 53 for emitting an optical signal, an IC 52 for driving the laser diode 53, and a lens system 54, which constitute an optical transmission system. This optical transmission system is arrayed in a plurality of rows in parallel in the module body 51, which performs the optical signal parallel transmission.

[0161] Fig. 26 only shows an enlarged optical fiber array 40. The optical fiber array 40 comprises a lower plate 41 in which a plurality of V-shaped grooves 43 are formed, and an upper plate 42 fixed on the lower plate 41. Glass parts of the optical fibers 44 which are not coated are positioned in the V-shaped grooves 43. The reference numeral 45 denotes a guide pin groove to which a guide pin is inserted.

[0162] As shown in Fig. 27A and Fig. 27B, the module body 51 may comprise a waveguide substrate 50 on which a plurality of optical waveguides 55 are formed. In this case, as shown in Fig. 28, a guide pin 56 may be used for coupling the waveguide substrate 50 with the optical fiber array 40, and the waveguide substrate 50

and the optical fiber array 40 may be fixed after an optical axis is aligned with adhesive. Further, the optical fiber array 40 may be fixed to the module body 51 (case) at parts denoted by the reference numeral 57 in a sealing state, using solder or a YAG laser. The adhesive which has the refractive index matching feature, e.g., ultraviolet hardening type adhesive is used to fix the coupling faces of the optical fiber array 40 and the module body 51.

[0163] Further, as shown in Fig. 29A-Fig. 29C, an inner space of a guide pin groove 45 for coupling an optical connector may be sealed with solder 59 or others. In this example, the guide pin groove 45 is a through hole.

[0164] As shown in Fig. 30A and Fig. 30B, if the optical fiber array 40 and the optical waveguide substrate 50 are pressed and fixed, with clips 39 inside the case of the module body 51, reliability is further increased.

[0165] The optical fiber array 40 comprises a coupling housing 58a for coupling the parallel transmission module with another optical fiber module F at the periphery of the optical fiber array 40, as shown in Fig. 25A, which is what is called a push-pull type. The coupling housing 58a is coupled with a coupling housing 58b of an optical connector comprising an optical fiber array F to be one-body (Fig. 25B).

[0166] Further, as shown in Fig. 31, a metal sleeve 60 may be put at the periphery of the optical fiber array 40. The metal sleeve 60 is the same type as the sleeve 8 in the embodiment 1, and a window part 61 is formed at a central portion of the sleeve 8. In this case, solder is filled in a gap between the metal sleeve 60 and the optical fiber array 40. The metal sleeve 60 may be square or round and may be designed corresponding to a module. The material of the metal sleeve 60 is preferably amber or covar which has the same thermal expansion as that of the optical fiber array 40.

[0167] Fig. 27A and Fig. 27B show a typical example of coupling of a parallel transmission module with an optical connector. The waveguide substrate 50 comprises optical waveguides 55 of 1x8 branch and the optical array 40 is provided at both ends of the waveguides 55. An optical fiber array F of an external optical connector is coupled to the optical fiber array 40. As one example of the coupling, the optical fiber array 40 is coupled with the optical fiber array F of the external optical fiber array F by a clip, e.g., a plate spring clip 62.

[0168] Fig. 26 is a perspective view showing basic structure of the optical fiber array comprising guide pin grooves. In Fig. 26, guide pin grooves 45 are not required if there is another positioning means. A housing 58a such as a push-pull type housing shown in Fig. 25A, may be provided at outside of the optical fiber array 40. The guide pin grooves 45 may be processed individually from both sides as shown in Fig. 28, and a number of guide pin grooves does not have to be two at the end.

[0169] Fig. 32 is a horizontal sectional view showing an example of an optical fiber array 40 which is put be-

tween an lower and upper plates 41 and 42 and which is fixed and sealed with solder. That is, Fig. 32 illustrates the airtight sealing of the optical fiber array 40 which is achieved by putting the optical fibers 44 between the lower and upper plates 41 and 42, and fixing and sealing, e.g., with solder 6 for coupling glass. The optical fiber array 40 may be sealed and coupled using low melting point glass instead of the solder 6.

[0170] The solder used in the optical module is a significant subject in reliability control of the optical fiber array, the module or others, and it is preferable that solder is used only for fixation of glass parts of the optical fibers since coated parts of the optical fibers melt on contact with solder and generate a large quantity of gas.

[0171] The solder is preferably fed from the end of the optical fiber while ultrasonic oscillation is applied, and as shown in Fig. 33, for example, a window part 61 is preferably provided because this location is to be the boundary between solder and adhesive. The advantage of providing such a window part 61 is that a gap spreads more at the window part, which prevents the solder from rising and which controls the optical fiber positioning.

[0172] The lower plate 41 is made of silicon and surfaces of guide pin grooves 45 are oxide films, which are preferred from aspects of coupling with the upper plate 42 and adhering with solder.

[0173] As shown in Fig. 33, the upper plate 42a on which guide pin grooves 45 are formed is bonded with the lower plate 41, and the upper plate 42 receives downward force by the upper plate 42a and pushes optical fibers 44.

[0174] It is desirable that Young's modulus E of the upper plate 42 is less than or equal to that of the upper plate 42a and the lower plate 41. This is because the upper plate 42 is easily polished if Young's modulus of the upper plate 42 is small when the end face is polished, which results in this part not projecting from the end face.

[0175] Further, the airtight sealing (hermetic sealing) is achieved by using solder and low melting point glass to fix the optical fiber array 40 and the case of the module body 51.

[0176] In this case, it is preferable to increase reliability of a metal coating or to deposit a carbon coating on the optical fibers 44 in order to ease the adhesive of solder.

[0177] In particular, the carbon coating can suppress the cracking on the optical fiber surface and breaking of the optical fiber when the optical fiber receives heat effects of 200 °C or above during solder fixation.

[0178] It is preferable that solder is suitable for coupling glass composing an optical fiber, for example, the solder to which the additive agent such as Zn, Sb, Al, Ti, Si or Cu is added. In this case, a compounding ratio of the additive agent to solder is 0.01-5 weight per 100 weight of solder, and more preferably 0.05-1.5 weight. If the compounding ratio of the additive agent is less than 0.01 weight, the junction strength is insufficient for

glass, and if it exceeds 5 weight, the characteristics of solder itself is lost, and the junction strength does not improve.

[0179] The lower plate 41 and the upper plate 42a may be coupled together without adhesive but by anode coupling, or direct coupling; consequently, reliability of bonding (hermetic sealing) can remarkably be improved.

[0180] In the case of anode coupling, it is preferable that the lower plate 41 made of silicon or zirconium and the upper plate 42a made of glass such as aminosilicate glass, silicon, or silicon having a glass deposited film are piled up and bonded by applying 1000V at about 400 °C.

[0181] The coupling method is not limited to anode coupling and direct coupling but the bonding method can be arbitrarily employed, e.g., vapor deposition as long as the same effects as the direct sealing and the others are obtained. The direct coupling is to make a silicon surface to be specular and heated to 1000 °C or above for coupling.

[0182] If the guide pin grooves 45 are provided, its sealing is a problem. There are shown the structures of airtight sealing of the guide pin grooves in Fig. 29A-Fig. 29C. Sealing of the inner part of the guide pin 56 with the solder 59 or YAG welding is illustrated in Fig. 29A.

[0183] The guide pin 56 is for initial alignment, and the alignment positioning is desirably set in the clearance range of the guide pin 56 and the guide pin hole.

[0184] Fig. 29B illustrates a case that the guide pin grooves 45 do not penetrate and the inner parts of the upper and lower plates are bonded.

[0185] Fig. 29C illustrates a case that the guide pin grooves 45 penetrate the waveguide substrate 51 and are all located outside the case of the module body 51 to handle airtight sealing and the guide pin grooves separately. As described above, the guide pin grooves 45 are preferably processed to penetrate and provided outside the module body. The optical fiber guide grooves (holes) and the guide pin grooves (holes) of the optical fiber array are processed on the same substrate; however, the optical fiber guide grooves and the guide pin grooves may be formed on the different substrate. With such structure, 180° inverting coupling can be made possible.

[0186] There are shown an optical fiber array 40 provided with a window part 61 for applying pressure in Fig. 33. With such structure, the optical fibers 44 are pressed and fixed with the separate upper plate 42.

[0187] That is, the optical fiber array 40 comprises a separate upper plate 42 other than the upper plate 42a. Then, the adhesive is injected from the window part 61 to fill a gap between the separate upper plate 42 and the lower plate 41 with solder. It is natural that the lower and upper plates 41 and 42a may be bonded by anode coupling or direct coupling. It is preferable that the guide pin grooves 45 are sealed in a view point of airtight sealing since the solder does not go inside the guide pin

grooves 45 when the solder is injected.

[0188] The alternative example of Fig. 33 is shown in Fig. 34. In Fig. 34, a slit-shaped opening 61a is provided instead of the window part 61 of Fig. 33, and optical fibers are pushed and fixed with an upper plate 42.

[0189] In Fig. 33 and Fig. 34, the guide pin grooves 45 are processed up to the middle and later bonded and sealed, which has an advantage of fixing the optical fibers without the solder flowing into the guide pin grooves 45 when the solder is injected (e.g., ultrasonic glass solder is injected) from the bonding and sealing side.

[0190] Optical fiber arrays with the various MFD (mode field diameter) are illustrated in Fig. 35A-Fig. 35D. With this MFD, the allowance of decentering becomes wide and its adjustment becomes easier.

[0191] Fig. 35A is a schematic view showing the MFD of the optical fiber array 40 on the module side being enlarged, what is called an enlarged MFD 69.

[0192] In this case, the MFD of the optical fiber array 40 on the module side is preferably enlarged 20% or above than the MFD of the standard single-mode optical fiber, and more preferably enlarged 100%.

[0193] Accordingly, the MFD of the optical fiber array at both ends is preferably enlarged 12 μm or above, and more preferably enlarged 19 μm.

[0194] Fig. 35B is a schematic view showing a case that the MFD of the optical fiber array 40 is made large and the MFD of the optical fiber array F on the optical connector side is converted.

[0195] Fig. 35C is a schematic view showing a case that the GI optical fiber 68 is set apart from the optical fiber array 40 by a certain length L (e.g., 0.8mm) on the same substrate to add the operation of a condensing lens. The outer diameter of the GI optical fiber 68 is preferably similar to that of the SM fiber but may differ in ±50%. Further, a residual stress relaxation type is preferably used for the MFD conversion.

[0196] Fig. 35D is a schematic view showing a case that the MFD of two kinds of optical fibers matches in the optical connector by fusing and coupling two kinds of the optical fibers. Note that the reference numeral 67 denotes a diffused and coupled portion.

[0197] Accordingly, it is preferable that the MFD of the optical fiber at the coupling end in the external optical connector is partially enlarged.

[0198] Further, the MFD of the optical fiber is enlarged 20% or above by concentrating residual stress in a core region to lower a refractive index of the core region as compared with a case of the residual stress being removed.

[0199] Furthermore, the optical fiber having the predetermined length in the optical connector desirably has a fused and adhered portion.

[0200] Fig. 36A and Fig. 36B show schematic views showing a case that the end face of the optical fiber array is deposited with non-reflective coating or diagonally polished to couple an optical fiber at an oblique angle.

[0201] There are shown one type of the optical fiber

arrays in Fig. 36A and Fig. 36B, which the end face of the optical fiber array 40 is deposited with non-reflective coating or diagonally polished to couple the optical fiber at an oblique angle, but the optical module constituting the optical connector may be a combination of a plurality of optical modules F_1 and F_2 .

[0202] As the adhesive for fixing the optical fibers, the adhesive which has high heat resistance, for example, quantity of gas generation is 1% or below at $260^\circ\text{C} \times 10$ seconds, e.g., epoxy resin adhesive is desirable.

[0203] The general optical connector in which the MFD of the optical fiber at the coupling end in the optical connector is partially enlarged has low loss against the decentering of the optical connector, which results in the achievement of low-loss coupling and which is preferable in a view of stability of removing and installing loss.

[0204] One example of such an optical fiber array 40 is shown in Fig. 37. The MFD of the optical fiber preferably is enlarged at least 20% or above as compared with a case of the residual stress being removed, in such a manner that residual stress in a core region is concentrated to lower a refractive index of the core region.

[0205] Further, the optical fiber having the predetermined MFD in the optical connector desirably has a fused and adhered portion 75.

Working example

[0206] Twelve single mode fibers were used, and the silicon substrate which was processed to form the V-grooves was bonded with a glass plate by anode-coupling, so that the optical fibers were pressed between the silicon substrate and the glass plate. Successively, the solder was injected to seal the whole structure while ultrasonic oscillation is applied (see Fig. 33).

[0207] The optical fiber array was about 10 mm in total length and 2.0 mm in thickness. The optical fibers were positioned within $1\ \mu\text{m}$. The guide holes were processed up to middle and the other parts were bonded to be sealed.

[0208] The LD module was aligned and positioned through the lens array and fixed to the case with solder. An IC for driving the optical fiber array was included in the LD module and sealed in airtightness.

[0209] Note that the metal sleeve processed by press-working was formed at the periphery of the optical fiber array in order to make the fixation to the case with solder easier, and the metal sleeve and the case were fixed with solder.

[0210] Further, a gap between the optical fiber array 40 and the metal sleeve 60 was filled with solder. The shape of the metal sleeve 60 is not limited. It may be square or round and it can be designed in accordance with the module. A protuberance (gill) may be provided on the metal sleeve 60 and welded by YAG.

[0211] Note that the metal sleeve 60 may be made of amber or covar which has comparatively the same thermal expansion as that of the optical fiber array 40.

[0212] The multifiber optical connector was coupled to the optical fiber array 40, and the loss in the coupling portion was measured. It was found that the average of 12 fibers was about 0.35 dB which would not be a problem in practice.

[0213] The push-pull type housing was installed on the optical connector to be connected to make the manipulation easier.

[0214] The optical connector the MFD of which was enlarged from $9.5\ \mu\text{m}$ to $18\ \mu\text{m}$ and the optical fiber array were tested. The loss was improved to about 0.20 dB and the dispersion of removing and installing was ± 0.02 dB, which showed the tendency of stabilization.

[0215] Further, the optical fibers were fixed with solder, so that the non-reflective coating was easily deposited thereto. As a result of testing, it was found that the reflective coating which is 30 dB or above to $\lambda=1.3\ \mu\text{m}$ could be deposited.

[0216] As described above, the parallel transmission optical module according to the present embodiment can convert the conventional pigtail type or jumper type module to a receptacle type module and make the manufacture and assembling operation easier. The optical fiber ribbon does not need to be installed, which leads the module to be compact and the packaging density to be increased.

[0217] With the use of the anode-coupling and the direct coupling, a number of parts decreases, and the assembling with high reliability can be possible. Further, the sealing of the guide pin grooves is easily achieved if the grooves are processed up to the middle by anode-coupling or direct coupling.

[0218] The holding member for the optical fibers is provided separately (see Fig. 33), so that the optical fibers are surely pushed into the V-shaped grooves and the $1\ \mu\text{m}$ eccentricity can be easily achieved.

[0219] The loss and the dispersion of removing and installing can be decreased by converting the MFD of the optical fiber array and the optical connector.

[0220] When the optical fiber arrays are coupled with the waveguide member and the guide pin, the aligning process is not required. Further, when the spring pushes the fibers inside the module, the reliability is further increased.

[0221] As shown in Fig. 29A, if the inner parts of the guide pin grooves are sealed, the operation of injecting the solder from the other end becomes easier because the solder does not applied to the guide holes.

[0222] Further, the optical fiber has the enlarged MFD, so that the connection between the optical connectors is made easier.

Embodiment 5

[0223] The parallel transmission module according to the present embodiment is explained in order of manufacturing processes with reference to the accompanying drawings.

[0224] First, each of optical fibers 1 is placed in each of V-shaped grooves 101a which are formed on a lower plate 101, and an upper plate 102 is put thereon. Thereafter, one end of the lower and upper plates 101 and 102 which hold the plurality of the optical fibers 1 are inserted into an opening 103 at a central portion of a metal flange 104 (Fig. 38 and Fig. 39). At this point, support plates 106 having V-shaped grooves 106a for supporting guide pins, which will be described later, are provided at the both sides of the lower plate 101 in a cross direction. The upper and lower plates are inserted until the support plates 106 touch the flange 104. A metal sleeve 105 for protecting the lower and upper plates 101 and 102 is fixed to an opening at the opposite side of the flange 104. After the insertion is completed, the inserted ends of the lower and upper plates 101 and 102 project from the end face of the metal sleeve 105 to the outside (Fig. 39).

[0225] Next, the ends of the lower and upper plates 101 and 102, which project from the metal sleeve 105, are soaked in the solder bath (see Fig. 18C), and high frequency oscillation is applied to the solder to fill the solder up to the other opposite end (Fig. 40). Then, the solder is filled between the metal sleeve 105 and the flange 104, and between the lower and upper plates 101 and 102 which hold the optical fibers 1 and the parts are all fixed in airtight. Note that the hermetic sealing member, e.g., low melting point glass can be used besides the solder.

[0226] Next, both ends of the lower and upper parts 101 and 102 are polished to remove the adhered solder. Then, the optical fibers are exposed to be specular (Fig. 41).

[0227] Thereafter, guide pins 108 are placed in the V-grooves 106a of the support plates 101 and 102. Then, a clumper 109 is put at the peripheries of the guide pin 108 and the lower and upper plates 101 and 102 so as to press them together. Consequently, the guide pins 108 are fixed in the V-shaped grooves 106a (Fig. 42).

[0228] Next, a protective sleeve 110 is put and fixed around the clumper 109 so as to cover the clumper-provided portion (Fig. 43). Thus manufactured optical fiber array 100 is shown in Fig. 44A-Fig. 44D.

[0229] Next, the optical fiber array 100 is inserted into a module body 120 which comprises a light emitting device array or a light receiving device array, and an IC circuit array corresponding to the device (Fig. 45). The solder or YAG welding is used to fix the parts entirely in an airtight sealing. Then, the parallel transmission module is completed (Fig. 46).

Embodiment 6

[0230] The other embodiment of the parallel transmission module will be explained with reference to the accompanying drawings. The structure of the parallel transmission module of the present invention is similar to the one shown in the embodiment 5, and the same

parts are represented by the same reference numerals.

[0231] Similar to the embodiment 5, in the parallel transmission module of this embodiment, optical fibers 1 are positioned by a lower plate 101 and an upper plate 102. Then, the optical fibers 1, the lower and upper plates 101 and 102, and the flange 104 are fixed to be a solid body by the hermetic sealing member such as solder or low melting point glass. The parallel transmission module further comprises guide pins 108 which are supported in the V-shaped grooves 106a of the support plate 106. Further, the optical fibers 1 are positioned in the V-shaped grooves 101a of the lower plate 101.

[0232] In particular, solder or low melting point glass is suitable for hermetic sealing member in a view of airtight sealing of the parts in the optical fiber array and in a view of reliability control of the optical fiber array and the module.

[0233] To inject the solder from the end of the optical array is preferably performed while ultrasonic oscillation is applied. In this case, if a window part (not shown) is provided on the flange 104, clamping the optical fibers 1 with the lower and upper plates 101 and 102 can be ensured at the window part.

[0234] One advantage of providing such a window part is widening a gap to prevent the solder from rising, which leads the control of optical fiber positioning.

[0235] For the solder material, it is preferable that the additive agent such as Zn, Sb, Al, Ti, Si or Cu is added to general Pb-Sn alloy, which is suitable for bonding optical fiber glass. The ultrasonic oscillation is applied to solder during bonding.

[0236] As shown in Fig. 47A-Fig. 47D, a wall 112 and the lower plate 101 are preferably made of Si-glass or Si-Si solid phase bonding.

[0237] Further, the solid phase bonding may be anode-bonding or may be direct-bonding of Si-Si.

[0238] Providing an oxide film on a surface of the lower plate 101 is preferable in a view of adhesion with the upper plate 102 or solder.

[0239] It is preferable that metal coating or carbon coating is deposited on the optical fibers 1 to improve the reliability in order to make the solder easily adhere on the optical fibers.

[0240] It is preferable that the flange 104, the optical fibers 1, and the lower and upper plates 101 and 102 are polished so as to be the same plane.

[0241] The upper plate 102 is easily polished if Young's modulus of the upper plate 102 is small when the end face is polished.

[0242] Further, as shown in Fig. 48A-Fig. 48D, the structure in which the optical fibers 1 and the lower and upper plates 101 and 102 project from the flange 104, is convenient for polishing.

[0243] Referring to Fig. 47A-Fig. 51E, a method of manufacturing an optical fiber array which constitutes a parallel transmission module will be explained.

[0244] Each of optical fibers 1 (not shown) is placed in each of V-shaped grooves 101a on a lower plate 101,

and an upper plate 102 is piled thereon to clamp the optical fibers 1. Next, a flange 104 which surrounds the periphery is installed and fixed by solder as shown in Fig. 48A-48D.

[0245] Its rear end is soaked into the solder bath (not shown) to seal the inside of the flange 104, and the solder injected from the rear end is made to reach the other end. In this case, the sealing parts at both ends are protuberance 111.

[0246] Accordingly, as shown in Fig. 51A-Fig. 51E, the solder is adhered on the flange 104, the step, and the entire rear end face of the optical fiber to make the rear end of the optical fiber array to be a metal part. That is, as shown in Fig. 49, it is understood that the lower and upper plates 101 and 102, the wall 112, and the optical fibers 1 are surrounded by the solder 113.

[0247] Next, both ends thereof are polished (Fig. 50A-Fig. 50D), and thereafter, the guide pins are inserted and fixed to the V-shaped grooves 106a provided at the end. This process is not necessary in a case of coupling an optical device at its end face or in a case of using another coupling means besides the guide pins.

[0248] As shown in Fig. 51A-51E, a protective sleeve 110 is preferably provided at the periphery of the optical fiber array if necessary in a view of protecting the inside of the optical fiber. In this case, the material of the protective sleeve 110 may be plastic.

[0249] Thus manufactured optical fiber array is polished at both ends to be entirely and hermetically sealed. Further, the guide pins 108, which are provided if they are necessary, are fixed by clampers 109 which are metal springs. Moreover, the advantages of the optical fiber array are simplifying the coupling between the optical connector or the optical device in the module body and the optical fiber array, and making the coupling operation easier.

[0250] Referring to Figs. 52A-Fig. 52D, a method of manufacturing an optical fiber array which constitutes part of a parallel transmission module will be further explained.

[0251] First, each of optical fibers 1 (not shown) is placed in each of V-shaped grooves 101a of a lower plate 101, and an upper plate 102 is piled thereon to clamp the optical fibers 1 and then bonded and fixed as shown in Figs. 53A-53C.

[0252] As shown in Figs. 53A-53C, it is important that walls 112 provided on the lower plate 101 prevent the flow of fixing agent 113a (solder or heat resistant adhesive) which is injected from the end so that the solder does not flow into the V-shaped grooves 106a of the support plate 106, and that the injecting condition is controlled so that the fixing agent does not reach the rear end.

[0253] Figs. 54A-54C show a state that one end of an optical fiber array is polished: Fig. 54A is its top view, and Fig. 54B is its side view, and Fig. 54C is a vertical sectional view of its end.

[0254] Fig. 55A-Fig. 55C show schematic views

showing a state that guide pins are inserted into the module at the front end and fixed at the rear end by solder. The guide pins 108 are inserted into the V-shaped grooves 106a provided at the end face of the module on the front side, and the guide pins 108, the optical fibers 1, and the metal flange 110a are fixed with solder 113 at once. The inside of the metal flange 110a is completely sealed with solder 113.

[0255] As shown in Fig. 56A-Fig. 56C, both end faces of the optical fiber array are polished, and then the optical fiber array is completed.

[0256] Thus manufactured optical fiber array, e.g., shown in Fig. 56A is polished at both end faces, and completely and hermetically sealed. Moreover, the optical fiber array can be easily coupled with an optical connector, an optical device, or others in the module, and the coupling operation is simplified.

[0257] This will be described in more detail.

[0258] Fig. 57 shows a configuration that the solder injected from the end does not flow into the V-shaped grooves 106a, which is similar to the one shown in Fig. 53A. In this example, walls 112 are provided on the lower plate 101 and/or the support plate 106, which shows frame structure.

[0259] The structure of walls 112 may be the one shown in Fig. 57, and in particular, the frame structure shown in Fig. 58 is preferable. With this structure, the reliability of the upper plate 102 fixation is improved.

[0260] Fig. 59 shows a state that a clumper 109 for clamping a thing resiliently holds the positioned guide pins 108.

[0261] As shown in Fig. 59, it is desirable that the guide pins 108 which are put in the V-shaped grooves 106 which hold the guide pins are exposed at least a part of the upper portion, and that this portion is fixed with the clumper 109 from an aspect of the guide pins 108 fixation.

[0262] Fig. 60 is a schematic view showing one example of modified guide pins. As shown in Fig. 60, there are steps at a part of the guide pin 108, and the guide pin may be resiliently clamped at the steps. In this case, the guide pin is clamped at the steps 108, which prevents the guide pins 108 from falling out.

[0263] The guide pin 108 is made of ceramic such as zirconia, which is preferable from the aspects of high precision and reliability.

[0264] Fig. 61 shows one aspect of the coupling end face of the external optical connector and the coupling end face in the parallel transmission module.

[0265] As shown in Fig. 61, the lower and upper plates 101 and 102 are preferable to have convex portions protruded over the V-shaped grooves 106a which are for guide pins, which guide pins are located at the coupling end face (front end) of the external optical connector. Further, it is preferable that the lower and upper plates 101 and 102 protrude from the V-shaped grooves 106a at the coupling end face (rear end) in the module, which is a shape of convexity.

[0266] The advantage of the convex shape is limiting the region on which the solder adheres.

[0267] Further, it is desirable that the flange 104 comprises a region in which a distal wall 104b which attaches one end face of the support plate 106 for holding guide pins, and a step 104a which is smaller than the distal wall 104b as shown in Fig. 61.

[0268] The optical fiber array according to the present embodiment may be positioned and fixed to the optical device such as the LD array, the lens array or others, by using adhesive after alignment thereof, solder or YAG laser for bonding to the case of the optical module, or guide pins. Note that this is the same in a case of coupling the optical fiber array with the waveguide substrate.

[0269] The V-shaped grooves 106a may be processed from the both ends of the optical fiber array separately. A number of guide pin grooves does not have to be two at the end. The V-shaped groove 106a for the guide pin does not have to be on the optical fiber array side if there is another positioning member (e.g., providing a guide pin grooves on the optical connector side), but may further comprise housing mechanism such as a push-pull type on the outside of the optical fiber array.

[0270] Further, the shape of the metal flange 104 may be square or circular, and its material is preferably amber or covar alloy the thermal expansion of which is comparatively the same as the optical fiber array.

[0271] Fig. 62A and Fig. 62B are schematic views showing optical fibers the MFD of which is converted in part or in whole parts.

[0272] In Fig. 62A and Fig. 62B, it is preferable that the optical fiber 40a is formed in which the MFD is enlarged (shrunk) to 12 μ m or above and more preferably 15 μ m or above in part or the whole portion so that the both ends of the optical fiber array 40 are suitable for fusing and connecting with the other optical connector. Further, in a view of angle loss, it is preferably 20 μ m or above and 50 μ m or below. The optical fiber 40a of Fig. 62A has the MFD of 30 μ m in full length, and the optical fiber 40a of Fig. 62B has the MFD of 30 μ m at one end in the module body 120, and has the MFD of 9.5 μ m at the other end located outside the module body 120. The optical fiber 40a of Fig. 62B is a standard single mode fiber. In Fig. 62A and Fig. 62B, the reference numerals 121 and 122 denote an LD array and a lens array which are provided in the module body 120, respectively.

[0273] In such a case; the optical connector has less changes due to loss against the decentering, which results in the achievement of the low-loss coupling. This case is preferable in a view of stability of installing and removing.

[0274] Further, the end face of the optical fiber array is not limited to be processed with surface grinding. It is possible that the end face is diagonally polished to couple an optical fiber at an oblique angle (e.g., 5-10°) and that the end face is deposited with non-reflective coating.

[0275] The fixing material for fixing an optical fiber is preferably the adhesive which has the high heat resistance and in which the gas generation is 1% or less of weight ratio when heated at 260°C for 10 seconds, e.g., epoxy resin adhesive in the case of using organic adhesive.

[0276] With thus constructed parallel transmission optical module, the sealing at the coupling end face of the module is sharply improved, since the optical fiber is fixed to the positioning member, which constitutes the optical module, by the fixing material, before the guide pin is fixed to the positioning member so as to improve the sealing of the coupling face to the multifiber optical connector, optical device or others.

[0277] Further, the optical module is not a conventional pigtail type, and the optical fiber ribbon is not added, so that the work efficiency or handling of the installation of a printed board of the module is sharply improved.

20 Embodiment 7

[0278] The embodiment of the parallel transmission module will be explained with reference to the accompanying drawings.

[0279] Fig. 73 is a schematic view showing basic structure of the parallel transmission module according to the present embodiment.

[0280] In Fig. 73, the reference numerals 600 and 511 denote an optical fiber array and a lens array, and 512 and 513 denote an LD array and a PD array which are formed in parallel, and 514 and 515 denote an IC for an LD and an IC for a PD connected to the LD and PD, respectively.

[0281] Note that the reference numeral 600 may be formed of an optical waveguide substrate but in the following explanation, an optical fiber array in which a plurality of optical fibers are arrayed will be explained.

[0282] As shown in Fig. 73, the LD array (light emitting device), and the PD array (light receiving device) are manufactured individually, and they are aligned through a lens array and positioned on the basis of the optical fiber array 600 when they are mounted.

[0283] In this case, the module is a transmittance-reception type parallel transmission module, and the optical fiber array is also a transmittance-reception type.

[0284] In this sort of modules, various optical devices may be included such as LD-PD, LD-LD, or LD-PD-LD.

[0285] On the other hand, in the conventional module, a light emitting module (transmitting module) and a light receiving module (receiving module) are formed separately, and in general, the transmitting module and the receiving module need to be mounted on a substrate separately in order to transmit an optical signal in both directions, which hinders the high mounting density.

[0286] Then, effects of forming the module as shown in Fig. 73 are that the module is miniaturized and that the mounting task is reduced as compared with the conventional module. Further, the cost of the optical fiber

array is reduced (polishing and installing optical fibers can be performed at once), which leads the achievement of the improvement of the mounting density and the reducing of mounting cost.

[0287] The optical fiber array according to the present embodiment may be positioned and fixed to the optical device such as the LD array, the lens array or others, by using adhesive after alignment thereof, solder or YAG laser for bonding to the case of the optical module, or guide pins. Note that this is the same in a case of coupling the optical fiber array with the waveguide substrate.

[0288] A guide pin may be used to couple the optical fiber array according to the present embodiment with the optical connector but the clip may be used.

[0289] Fig. 74 is a schematic view showing basic structure of the optical fiber array 600.

[0290] In Fig. 74, an Si chip is processed to form optical fiber V-shaped grooves 602, which forms a lower plate 606, and optical fibers 601 are positioned in the optical fiber V-shaped grooves 602 with accuracy of 1 μ m or below. Further, guide pin V-shaped grooves 603 are formed on the lower plate 606, and guide pins 604 are inserted in the guide pin V-shaped grooves 602 between the upper plate 605 and the lower plate 606 to position the optical connector (not shown).

[0291] A metal flange 609 (see Fig. 77) is provided on the outside of the upper and lower plates 605 and 606. The metal flange 609 is fixed to a module by solder, YAG welding or others.

[0292] In the case of installing the optical fibers 601 in the optical fiber array 600, a part or the whole can be fixed with solder to seal the module in an airtight state.

[0293] Further, a direction of an end face of the optical fiber array is not limited to a vertical direction against an optical axis direction, but the end face may be diagonally polished to incline in an oblique direction. Accordingly, the oblique angle coupling (e.g., 5-10°) can be made possible. Further, the non-reflective coating can be deposited on the end face of the optical fiber array.

[0294] The fixing material for fixing an optical fiber is preferably the adhesive which has the high heat resistance and in which the gas generation is 1% or less of weight ratio when heated at 260°C for 10 seconds, or hermetic sealing member such as solder or low-melting point glass. This point is the same as the other embodiments.

[0295] The hermetic sealing member is important in reliability control of the optical fiber array and the module.

[0296] For the solder material, it is preferable that the additive agent such as Zn, Sb, Al, Ti, Si or Cu is added to general Pb-Sn alloy, which is suitable for bonding optical fiber glass.

[0297] The metal coating or carbon coating is preferably deposited on the optical fibers 601 to improve the reliability in order to make the solder easily adhere to the optical fibers 601.

[0298] The reference numeral 607 is an optical fiber pressing plate which is useful for holding the optical fibers 601 in the optical fiber V-shaped grooves 602 with a presser such as a clip (not shown) from an optical fiber presser window 608.

[0299] The guide pin grooves 603 may be processed from the both ends of the optical fiber array.

[0300] The guide pin V-shaped grooves 603 are not necessary if there is another positioning member but may further comprise housing mechanism such as a push-pull type on the outside of the optical fiber array.

[0301] The shape of the metal flange 104 which is used in the present embodiment may be square or circular, and its material is preferably amber or covar alloy the thermal expansion of which is comparatively the same as the optical fiber array.

[0302] Fig. 75 is a schematic view showing an enlarged end face of the optical fiber array.

[0303] In Fig. 75, five channels of optical fibers 601 are arrayed with a 250 μ m pitch, and arranged corresponding to a LD (reference numeral 610) or corresponding to a PD (reference numeral 611), and each channel is arranged on the same axis with a 12mm pitch.

[0304] With such structure, the LD and PD arrays are aligned and positioned on a basis of an optical fiber array 600. Note that an array lens may be formed on one end of the optical fiber array if necessary.

[0305] Fig. 76A-Fig. 76D are schematic views showing one example of arrangement of light receiving devices and light emitting devices.

[0306] In the present embodiment, as shown in Fig. 76A, the arrangement is not limited to the same straight line arrangement, but for example, the arrangement may be the parallel line arrangement in which one is shifted with an interval of ΔH and arrayed in parallel with the other one (Fig. 76B), the two-dimensional arrangement in which one is arrayed in parallel with the other one with a space of ΔH (Fig. 76C), or the mixing arrangement in which fibers for LD and fibers for PD are mixed (Fig. 76D), or a combination of these. These can be designed in a view of the productivity and assembly of an LD and a PD. In Fig. 76A-Fig. 76D, a white circle denotes a light emitting device such as an LD, and a black circle denotes a light receiving device such as a PD.

[0307] In the above case, the embodiment is explained using the LD and PD as the optical devices, but the above case can be applied to an array of light emitting devices, e.g., LEDs or light receiving devices.

[0308] Fig. 77 is a schematic view showing one example of structure of an optical fiber array in which optical fibers are arrayed in two-dimension corresponding to the arrangement of such light emitting devices or such light receiving devices. In Fig. 77, the reference numeral 604' denotes a guide pin for adjusting a space ΔH , and the reference numeral 603' denotes a guide pin groove. Note that this can be also applied to GI optical fibers.

[0309] Fig. 78A and Fig. 78B are schematic views showing one example of the MFD enlarged conversion

or the MFD reduced conversion on the optical fiber array side or on the optical connector side which is for coupling an optical fiber array.

[0310] As shown in Fig. 78A and Fig. 78B, in a case of using SM optical fibers, in order to make the coupling with a light receiving device or a light emitting device easier, the MFD of the optical fiber may be enlarged (Fig. 78A) or reduced (Fig. 78B). Further, the MFD at one end of the optical connector which is coupled to the optical fiber array may be enlarged (or reduced).

[0311] In such a case, the optical connector or the optical fiber array has less changes due to loss against the decentering, which results in the achievement of the low-loss coupling. This case is preferable in a view of stability of installing and removing. Note that the reference numeral 621 denotes a state that the MFD on the optical fiber array side is large and the reference numeral 622 denotes a state that the MFD on the optical connector side which is coupled to the optical fiber array is gradually small. Further, in Fig. 78B, the reference numeral 623 denotes a typical SM (single mode) fiber provided on the optical connector side for coupling, and the reference numeral 624 denotes a state that the MFD of a fiber provided on the optical fiber array side is changed in the array.

Working example

[0312] The LD array of 10 channels and the PD array of 10 channels were coupled and aligned to a single mode optical fiber array of 20 channels through a lens array.

[0313] The MFD of the optical fibers in the optical fiber array was formed to about 30 μm , and it is designed so that the X-Y tolerance of the alignment becomes large.

[0314] An alloy housing (metal flange) which had low thermal expansion such as amber or covar alloy was formed on the outside of the optical fiber array, and the housing was hermetically bonded to a module housing.

[0315] The grooves corresponding to guide pins having a diameter of 0.7mm were processed in the optical fiber array, and the guide pins were holding in the grooves, and this location was hermetically sealed.

[0316] On the other hand, an external multifiber optical connector was installed in the push-pull housing, so that the optical connector was easily coupled with a transmittance/reception module.

[0317] The MFD of the general single mode optical fiber was about 9.5 μm and the MFD converting portion as shown in Fig. 78A was formed in the multifiber optical connector to form the multifiber optical connector in which the MFD was converted from 30 μm to 9.5 μm .

[0318] The MFD conversion was achieved by fusing and connecting a residual stress relaxation type optical fiber.

[0319] The obtained transmission-reception module showed good performance in coupling loss and transmission characteristic, and the mounting density on the

printed board was improved twice or more.

[0320] As described above, according to the present embodiment, the following effects are shown.

(i) The mounting density on a printed board is improved since an LD array and a PD array are packaged together.

(ii) The cost is decreased since only one set of a package housing or an optical fiber array is needed (conventionally, two sets are needed) and mounting operation is processed at the same time.

(iii) The improvement of working efficiency of alignment and the stabilization of optical connector coupling loss can be achieved. This is because the tolerance of the alignment or the optical connector coupling is increased by converting the MFD of an optical fiber array or a multifiber optical connector.

Embodiment 8

[0321] In Fig. 63, a housing structure to be used with an embodiment of the present invention includes three housings A, B and C.

[0322] The housing A is substantially square tubelike, and fixed to a backboard 301 which is a diaphragm which separates an apparatus to be connected to an optical module into an internal part and an external part. The housing A accommodates the housing B.

[0323] The housing B has a function to receive and hold a push-on type optical connectors 302 and 303 which have optical fiber arrays at the tip as illustrated in Fig. 6. The housing B is accommodated in the housing A so as to be slidable.

[0324] The housing C comprises two housings: upper and lower. The structure of two housings is to sandwich and hold a parallel transmission module. Note that Fig. 68 shows one of two divided housings. Further, the housing C accommodates two parallel transmission modules, e.g., shown in Fig. 46 and is fixed at one end of a printed board 304 provided IC chips for driving the parallel transmission module or for processing a received signal. Note that in this embodiment, the housing C contains a parallel transmission module LD for transmittance which comprises an LD array and a parallel transmission module PD for reception which comprises a PD array. It is also noted that the housing C comprises a fin 237 for releasing heat (see Fig. 64).

[0325] As shown in Fig. 64, when the optical connectors 302 and 303 are inserted into the housing A and B fixed on the backboard 301 in a direction as an arrow 305 indicates, the housing B in the housing A holds the optical connectors 302 and 303 at the periphery thereof. With this states, one end of the housing B touches a distal wall 211 located on a distal end of the housing A, and a protrusion 221 provided at the other end of the housing B touches a protrusion 212 located at an opening end of the housing A. Accordingly, the both ends of the housing B touch a part of the housing A, which limits

the operation of the housing B in the housing A. Consequently, the optical connectors 302 and 303 are held in the housing A.

[0326] Next, as shown in Fig. 64, the housing C holding the parallel transmission modules LD and PD is inserted in the housings A and B in a direction as an arrow 306 indicates. At this time, as shown in Fig. 65, holding parts 231 of the housing C go across over tapered parts 213 of the housing A to sandwich the end portion of the housing B. Further, contact parts 232 protruding from the end of the housing C touch one end of the housing B.

[0327] As the housing C is further pushed, the housing B is pressed by the contact parts 232 of the housing C to be displaced following the pushing direction (direction of an array 306), whereby, as shown in Fig. 66, the protrusion 221 of the housing B is displaced across over the protrusion 212 of the housing A. In result, the engagement of the protrusion 221 with the protrusion 212 is released, and the housing B protrudes from the rear end of the housing A and is able to be displaced following the array 306. That is, the limitation of the slide of the housing B is released. However, the range of displacement is not unlimited. It is limited as a step 223 of the housing B touches the backboard 301. Note that the distance of displacement is preferably about 2mm.

[0328] In this state, the housing B is sandwiched by the holding parts 231 of the housing C, and the housing B and the housing C are coupled together. At this time, the housing A does not involve in this coupling but guides the coupled housing B and housing C.

[0329] With such coupling structure, if the printed board 304 is displaced to some extent, this force does not directly affect the backboard 301.

[0330] On the other hand, in the case of releasing this coupling, the housing C is pulled in a direction of the arrow 307 (see Fig. 67). As the housing C is thus displaced, claws of the holding parts 231 in the housing C engage with the steps 224 of the housing B. Consequently, the housing B is pulled by the housing C in a direction of the arrow 307 (see Fig. 66).

[0331] As the housing C is further separated in the direction of the arrow 307, as shown in Fig. 67, the protrusion 221 of the housing B is displaced across over the protrusion 212 of the housing A. At the same time, the holding parts 231 of the housing A are displaced across over the tapered parts 213, and the housing B held by the housing C is released. Whereby the housing B is returned at initial position, and its displacement is limited by the housing A again. The coupling of the housing B with the housing C is released and the housings B and C are separated from each other.

[0332] As described above, the coupling and releasing of two parallel transmission modules are conducted.

[0333] Further, in this case, the housing C comprises a parallel transmission module LD. It is preferable that a shielding plate 235 shown in Fig. 68 is provided in order to prevent an optical signal emitted from the LD module from entering operator's eyes. The shielding plate

235 is provided at an inserting end of the housing C and pivotally supported by a support rod 236 fixed to the housing C. When the module is coupled, the shielding plate 235 is pushed into the inner part of the housing by the opposing module. When the coupling is released, the shielding plate 235 is returned at initial position. This function prevents the optical signal from entering the operator's eyes. Note that only one example of the opening-closing structure of the shielding plate 235 is shown here but another structure can be employed.

Embodiment 9

[0334] Another embodiment of the housing structure to be used with the invention will be explained with reference to the accompanying drawings.

[0335] Fig. 69 shows housing structure connecting two sets of the optical device arrays with external connectors.

[0336] In Fig. 69, the housing structure includes three housings A, B and C. The housing C contains two sets of parallel transmission modules 403. The parallel transmission modules 403 is constituted by making an optical device 403 which is a light emitting device array or a light receiving device array, and an optical connector receptacle part 402 comprising an optical fiber array (see Fig. 71) together to be a solid body. The housing B comprises two sets of push-on devices 407 with a spring push function, which is able to be inserted in the optical connector receptacle part 402 and which is able to be released and installed. Further, the housing A and the housing B are integrated with claws 408 which engage with claw tapered parts 409 before the housing C is coupled with the housing B. When the housing B engages with the housing C, the claws 408 are released, so that the housing A is free from the housings B and C.

[0337] Fig. 70A-Fig. 70C are schematic views showing a lock releasing of the housing B from the housing A.

[0338] In Fig. 70A, before the housing C is coupled with the housing B, the claw 408 engages with the claw tapered part. However, thereafter, the claw 408 crosses over the claw tapered part 409 (Fig. 70B) and the housing C is coupled with the housing B. In this case, the claw 408 has a 2mm rate of floating L and the housing A and the housing B are in a non-coupling state (Fig. 70C).

[0339] In Fig. 69, multifiber optical connectors 402' with optical fiber cords 423 connected are coupled to two sets of the push-on devices 407, and the multifiber optical connector 402' is a device which is able to be inserted in the housing B through the push-on device 407.

[0340] It is preferable that one of the optical devices 403 provided in two sets of the optical modules which are contained in the housing C is an LD array and the other is a PD array. Each optical module is individually fixed on the printed board 401. Further, it is preferable that the housing B is fixed on the backboard 410, sep-

arated from the parallel transmission module.

[0341] The housing C has the structure which splits into an upper and lower parts, and after the optical module is installed in the housing C, the upper and lower parts are combined (see Fig. 68).

[0342] Further, the optical module has a convex part and a concave part for positioning, and the convex part or the concave part is inserted to the corresponding part of the housing C. Accordingly, the relative alignment of the optical module with the housing C can be achieved with high precision and high working efficiency.

[0343] Furthermore, the shape of the convex parts and the concave parts in the two sets or plural sets of the optical modules may be different from each other, whereby the plural sets of the modules can be inserted without error and securely installed.

[0344] It is preferable that the housing C is constituted with the substrate and the cover plate. Then, it is desirable that the convex parts for positioning the optical fiber array at the end of the optical module are provided to engage the concave parts of the arrays for the LD and PD and after assembling, the cover plate is installed.

[0345] The cover plate may be made of metal, and the fin may be installed to form a conduction part for the internal heat radiation in order to improve the heat radiation.

[0346] The housing A desirably has the structure which comprises the housing B, and with this structure, when the claw 408 is released, the stroke can be made 0-2mm in the axis direction and more preferable 2mm or above. with this structure, if the position of the printed board 401 is off, e.g., ± 1 mm, the tight coupling of the optical module with the multifiber optical connector 402' can be achieved without the pressure affecting on the backboard 410.

[0347] The optical connector is preferably a multifiber and a push-pull type. In the push-pull type optical connector, the guide pin coupling type ferrule is pressed with the spring, and the coupling is released by the peripheral injector.

[0348] The housing system to be used in the present embodiment can be widely applied to the parallel transmission module, and more precisely, applied to the structure in which one end of the optical fiber array is coupled to the module optical system (optical device) and the other end is coupled to the optical connector.

[0349] Fig. 71 is a schematic view showing basic structure of a parallel transmission module provided in the housing system of the present embodiment.

[0350] In Fig. 71, an optical fiber array is at the end of a module and comprises an internal coupling end face for coupling an optical device in the module and an external coupling end face for coupling an external optical connector. Further, the optical fiber array comprises guide pins 422 at the external coupling end face, and a positioning member comprising an upper and lower plates 415 and 416, and a metal flange (not shown) at the periphery of the upper and lower plates are provided.

[0351] Optical fibers 412 are positioned at both end faces by the lower plate 416 and the upper plate 415. The optical fibers 412, the upper and lower plates 415 and 416, and the metal flange are fixed together with hermetic sealing member such as solder or low melting point glass. Further, the module comprises the guide pins 422 and the guide pin grooves 414. In this case, the guide pin grooves 414 are provided in the positioning member for optical fibers on the optical fiber array 411 side or on the optical connector 402' side, and the guide pins 422 are fixed in this grooves.

[0352] The optical fibers 412 are positioned in the fiber grooves 413.

[0353] It is important that the optical fiber array is entirely sealed with the hermetic sealing member and that both end faces are polished.

[0354] For the hermetic sealing member, it is preferable that the additive agent such as Zn, Sb, Al, Ti, Si or Cu is added to general Pb-Sn alloy, which is suitable for bonding optical fiber glass. These members are important from an aspect of airtightness of the parts in the optical fiber array and from an aspect of reliability control of various optical devices in the optical fiber array and the module.

[0355] To seal the optical fiber array, the hermetic sealing member is fed from the end of the optical fiber array by soaking the optical array in the hermetic sealing member. In such a case, it is preferable that the ultrasonic oscillation is applied to the hermetic sealing member. Further, a window part (not shown) or an optical fiber exposing part is preferably provided to assure the clamping of the optical fibers with the upper and lower parts at this location.

[0356] The advantage of providing such a window part or an optical fiber exposing part is that a gap spreads more at the window part, which prevents the solder form rising and which controls the optical fiber positioning.

[0357] Further, it is desirable that a wall (not shown) is provided at the lower plate 416. The wall and the lower plate 416 may be formed by the solid-phase bonding: Si-glass or Si-Si. The solid-phase bonding may be made by direct bonding of Si-Si.

[0358] Providing an oxide film on a silicon surface of the lower plate 416 is preferable in a view of adhesion of the upper plate 415 or in a view of adhesion of solder.

[0359] The metal coating or carbon coating is preferably deposited on the optical fibers 412 to improve the reliability in order to make the solder easily adhere to the optical fibers.

[0360] The end faces of the optical fibers 412, the upper and lower plates 415 and 416 and the metal flange may be polished to be substantially the same plane. They are easily polished if Young's modulus is small when the end face is polished.

[0361] Further, if the optical fibers 412, and the upper and lower plates 415 and 416 protrude from the metal flange, they are excellently polished.

[0362] Fig. 72 is a schematic view showing a light reception-emission module comprising an optical fiber array having a metal flange at the periphery of the module.

[0363] In Fig. 72, a reference numeral 422 is a guide pin, 411 is an optical fiber array, 417 is a positioning part, 418 is an IC part, 419 is pins, 420 is an array lens, and 412 is an LD or a PD array.

[0364] As shown in Fig. 72, the metal flange (not shown) is provided at the periphery of the optical fiber array 411 installed in the optical connector receptacle part 402. The guide pins 422 are fixed at the end of the optical fiber array 411. The module is coupled with the optical connector 402' or others by the guide pins 422. The LD or PD array 421 and the IC part 418 are connected at the rear end of the optical fiber array 411 through the array lens 420, and the module is coupled to another optical apparatus by the pins 419.

[0365] Further, the metal flange or others is installed on the optical fiber array 411 and fixed at the end of the module, whereby the optical connector receptacle part 402 as shown in Fig. 69 is formed.

[0366] The optical fiber array and the optical devices (LD or PD array, lens array or optical waveguide, or others) may be bonded after aligning with the adhesive, or may be bonded to the case of the optical module by solder or YAG laser, or may be bonded using guide pins.

[0367] The angle of an end face of the optical fiber array is not limited to a vertical direction against an optical axis direction, but the end face may be diagonally polished. Accordingly, the oblique angle coupling (e.g., 5-10°) can be made possible. Further, the non-reflective coating can be deposited on the end face.

[0368] In the present invention, the optical fiber array comprises optical fibers which are positioned by the upper and lower plates, but optical waveguides formed on the silica substrate may be used in the optical connector receptacle part without using the optical fibers. The guide pin grooves may be formed in the optical waveguide if necessary.

[0369] With use of the optical waveguide, the hermetic sealing is made easier, and when the pitch between the device and the optical connector is required to be changed, this process can easily be treated. Further, the function of the optical branching filter and the optical multiplexer can be provided in the receptacle part.

Working example

[0370] As one example, there will be described a structure of a push-pull coupling, which coupling is performed by coupling one set of module, which mounts one set of 12 channels LD arrays and one set of 12 channels PD arrays, and two sets of the 12-fibers single mode optical connectors through the backboard.

[0371] First, a housing C was made of polyphenylene sulfide (PPS) plastic.

[0372] A cover plate was made of metal, and had a fin to improve a heat radiation. A heat conduction con-

tacted with a portion between the cover plate and the module in order to make the heat in the module conduct easily.

[0373] The heat conduction easily contacted with the portion between the cover plate and the module by installing the cover plate.

[0374] The housing C was constituted with a substrate and the cover plate. The substrate had the convex parts for positioning the optical fiber array at the end of the optical module to engage the concave parts of the arrays for the LD and PD, and after assembling, the cover plate was installed.

[0375] A housing A comprised A housing B, and the stroke was made 2mm in axis direction when the lock was released. With this structure, if the position of the printed board is off, e.g., ± 1 mm, the coupling of the optical module with the multifiber optical connector can be achieved without the pressure affecting on the backboard. Both the housings A and B were made of PPS plastic.

[0376] In the push-pull type multifiber optical connector, a guide pin coupling type ferrule is pressed with a spring and the coupling is released by an injector provided with peripherals thereof.

[0377] A pitch of the 12-fibers optical connector was 16mm. The height of the housing C from the printed board was suppressed below 9.0mm regarding the mounting.

[0378] With this structure, the installing and releasing were repeated 500 times. It was assured that the module practically did not have any problems; the loss was within 0.4dB.

[0379] Further, with the structure, the optical transmittance-reception module and the multifiber optical connector could be coupled individually with the backboard, and the working efficiency was sharply improved.

[0380] Since the transmittance and the reception were included together, the space for installation was small and the handling was improved.

[0381] As described above, the housing structure to be used in the present embodiment can connect a plurality of optical device arrays which are made to be one body with the optical connectors, and the coupling process is made easier.

[0382] The embodiments 1-9 are explained separately only for the sake of convenience. Each embodiment relates to each other, and the component explained in one of embodiments may be used in other embodiments, and the combination of components may be used.

INDUSTRIAL APPLICABILITY

[0383] An optical fiber array to be used in the present invention can protect the boundary portion between a ribbon part of an optical fiber which is coated part and a glass part of the optical fiber from the heat when the ribbon part is fixed with the solder, since the boundary

portion is covered with the heat resistant adhesive.

[0384] In a parallel transmission module according to the present invention, a main body of module including a plurality of optical transmission systems and an optical fiber array including a plurality of optical fibers are made to be one body, so that the module is easily handled and a large space for installation is not required, which is different from a conventional module.

[0385] In a method of manufacturing a parallel transmission module according to the present invention, both end faces of an optical fiber array fixed to the module are entirely sealed with high airtightness, and a lens or an optical device provided in the module can sufficiently be protected.

[0386] In a housing system to be used with the present invention, a parallel transmission module can directly and easily be coupled and released to and from a multifiber optical connector, respectively, and the working efficiency can be sharply improved.

Claims

1. A parallel transmission module (M) transmitting a plurality of optical signals in parallel, said parallel transmission module comprising:

a module body (51) comprising a plurality of optical transmission systems (52, 53, 54) for transmitting said optical signals separately;

an optical fiber array (40) provided at one end of said optical transmission systems (52, 53, 54) provided in and fixed at said module body (51), comprising a plurality of optical fibers for optically coupling with said optical transmission systems individually; and

guiding means (45) for guiding another optical connector to couple with an optical coupling end face of said optical fiber array (40), said optical coupling end face being located at the opposite side to the end face optically coupled with said optical transmission systems,

wherein said guiding means is one of a guide pin for positioning said another optical connector to be coupled with said optical coupling end face of said optical fiber array (40) and a guide groove (45) for receiving a guide pin provided at said another optical connector to be coupled with said optical coupling end face of said optical fiber array, and wherein a flange member (104) is put at the peripheries of said first (41) and second plate (42),
characterized in that
 the optical fiber array (40) comprises

- a first plate (41, 101) comprising a plurality of

positioning grooves (43, 101a) for positioning said optical fibers;

- a second plate (42, 102) for pressing each said optical fiber provided in each said positioning groove (43, 101a) on said first plate (41, 101) into said positioning grooves (43, 101a); and
- support plates (106) provided at both sides in a cross direction of said first plate (41, 101) so as to protrude from both sides to support said guide pin;

wherein said optical fibers, said first and second plates for holding said optical fibers, and said flange member are fixed together, and wherein solder or low melting point glass is inserted into the space between the lower and upper plate and between the flange (104) and the metal sleeve (105) so that the solder or low melting point glass is filled in the space in substantially an entire cross section in a plane perpendicular to a longitudinal direction of said optical fibers (1) and said optical fibers (1) are fixed between said first (41, 101) and second plate (42, 102) airtightly by the solder or low melting point glass, as well as said metal sleeve (105) and the flange (104).

2. A parallel transmission module according to Claim 1,

wherein each of said optical transmission systems is optically coupled individually with optical fibers in said optical fiber array (40) and comprises one of an optical device (53) for emitting light or an optical device for receiving light, and a circuit device (52) provided corresponding to said optical device; and said optical transmission systems are provided in said module body (51) an array.

3. A parallel transmission module according to Claim 1,

wherein said module body (51) comprises a light emitting device array including a plurality of light emitting devices arrayed, and a light receiving device array including a plurality of light receiving devices arrayed, provided adjacent to said light emitting device array;

wherein each said optical transmission system comprises one of said light emitting devices constituting said light emitting device array and one of said light receiving devices constituting said light receiving device array; and

wherein one of said optical transmission systems is optically coupled with each optical fiber in said optical fiber array.

4. A parallel transmission module according to Claim

- 1, wherein said module body (51) comprises a waveguide substrate(50); and said optical transmission systems are a plurality of optical waveguides formed on said waveguide substrate (50).
5. A parallel transmission module according to claim 1, wherein said support plates (106) have a shorter length as compared with said first plate (101), and said flange member (104) touches one end face of said support plate (106).
6. A parallel transmission module according to Claim 1 further comprising a housing for holding said another optical connector to be coupled.
7. A parallel transmission module according to Claim 1, wherein convex portions (112) projecting from said first plate (101) in a height direction are formed along with adjoining regions between said first plate (101) and said support plates (106) at both sides of said first plate (101), and said convex portions (112) prevent said fixing agent filled in said first plate from flowing out into said support plates.
8. A parallel transmission module according to Claim 1 further comprising a clamp member (109) for holding and elastically pressing said guide pin against said support plate.
9. A parallel transmission module according to Claim 1, wherein an optical coupling end face on said another optical connector side of said optical fiber array protrudes from a position of the end face of said support plate in a longitudinal direction of said first (101) and second plates(102).
10. A parallel transmission module according to Claim 1, wherein said optical coupling end face on said module body side of said optical fiber array protrudes from a position of the end face of said flange in a longitudinal direction of said first (101) and second plates (102).
11. A parallel transmission module according to Claim 1, wherein said fixing agent is solder; and said optical fibers (1) are fixed between said first (101) and second plates (102) in an airtight state by said solder.
12. A parallel transmission module according to Claim 11, wherein said solder is Pb-Sn alloy; and said solder comprises one kind of additive agent selected from the group consisting of Zn, Sb, Al, Ti, Si, and Cu.
13. A parallel transmission module according to Claim 12, wherein said optical fibers (1) are carbon coated fibers.
14. A parallel transmission module according to Claim 1 further comprising a sleeve (110) put at the peripheries of said first (101) and second plate (102) for holding said optical fibers (1).
15. A parallel transmission module according to Claim 14, wherein said sleeve (110) is made of Ni-Fe alloy.
16. A parallel transmission module according to Claim 1, wherein said first plate (101) and said second plate (102) are bonded together by anode coupling.
17. A parallel transmission module according to Claim 1, wherein said optical fibers (1) arrayed in said optical coupling end face have a mode field diameter partially enlarged in the vicinity of said optical coupling end face.
18. A parallel transmission module according to Claim 17, wherein said mode field diameter is enlarged by concentrating residual stress in a core region to lower a refractive index of said core region; and said mode field diameter is enlarged 20 % or above as compared with a case of said residual stress being removed.
19. A method of manufacturing a parallel transmission module comprising:
- a first step of positioning an optical fiber (1) in every positioning groove (101a) formed in a first plate (101) having a plurality of such positioning grooves (101a), and pressing all of said optical fibers (1) into the positioning grooves by a second plate (102);
- a second step of putting a flange member (104) at the peripheries of said first (101) and second plate (102) holding all of said optical fibers (1);
- a third step of soaking one of the end faces of said first (101) and second plates (102), where the end faces of said optical fibers (1) are arranged, in a solder tab filled with solder or low melting point glass to fix said flange member

(104) at the peripheries of said first (101) and second plate (102);

a fourth step of filling solder of said solder tab into a gap between said first and second plates from one end to the other end for an airtight

sealing between said first and second plates and said optical fibers, and wherein solder or low melting point glass is inserted into the space between the lower and upper plate and between the flange (104) and the metal sleeve (105) so that the solder or low melting point glass is filled in the space in substantially an entire cross section in a plane perpendicular to a longitudinal direction of said optical fibers (1) and said optical fibers (1) are fixed between said first (41, 101) and second plate (42, 102) a fourth step being conducted at the same time as said third step, or right before or after said third step;

a fifth step of polishing both end faces of said first (101) and second plates (102) to make the end faces of all said optical fibers to be specular, whereby an optical fiber array is formed; and

a sixth step of fixing one end face of said optical fiber array at an optical coupling end face of a module body comprising a plurality of optical transmission systems to make said optical fiber array and said module body to be one body, and optically coupling said optical fibers in said optical fiber array individually with said optical transmission systems in said module body.

20. A method of manufacturing a parallel transmission module according to Claim 19, wherein in said fourth step, ultrasonic oscillation is used to fill said solder or low melting point glass in said first and second plates from one end to the other end.

Patentansprüche

1. Parallel-Übertragungsmodul (M), welches mehrere optische Signale parallel überträgt, wobei das Parallel-Übertragungsmodul folgendes aufweist:

einen Modulkörper (51), welcher mehrere optische Übertragungssysteme (52, 53, 54) aufweist, um die optischen Signale einzeln zu übertragen;

ein Lichtleiterfeld (40), welches an einem Ende der optischen Übertragungssysteme (52, 53, 54) vorgesehen ist und welches in dem Modul-

körper (51) vorgesehen ist und daran befestigt ist, mit mehreren Lichtleitern für einzelne optische Kopplungen mit den optischen Übertragungssystemen; und

Führungsmittel (45) zum Führen eines weiteren optischen Verbinders für eine Kopplung mit einer optischen Kopplungsendfläche des Lichtleiterfelds (40), wobei die optische Kopplungsendfläche an der gegenüberliegenden Seite zu der Endfläche vorgesehen ist, welche optisch mit den optischen Übertragungssystemen gekoppelt ist,

wobei das Führungsmittel entweder ein Führungsstift zum Positionieren des weiteren optischen Verbinders ist, welcher mit der optischen Kopplungsendfläche des optischen Faserfelds (40) gekoppelt werden soll, oder eine Führungsnut (45) zur Aufnahme eines Führungsstifts, welcher an dem weiteren optischen Verbinder vorgesehen ist, welcher mit der optischen Kopplungsendfläche des optischen Faserfelds gekoppelt werden soll, und wobei ein Flanschelement (104) sich an den Außenseiten einer ersten (41) und einer zweiten Platte (42) befindet,

dadurch gekennzeichnet, dass
das Lichtleiterfeld (40) folgendes aufweist:

- eine erste Platte (41, 101) mit mehreren Positioniernuten (43, 101a) zum Positionieren der Lichtleiter;
- eine zweite Platte (42, 102) zum Pressen jedes Lichtleiters, welcher in jeder der Positioniernuten (43, 101a) vorgesehen ist, auf die erste Platte (41, 101) in die Positioniernuten (43, 101a); und
- Lagerplatten (106), welche an beiden Seiten in Querrichtung der ersten Platte (41, 101) vorgesehen sind, so dass sie von beiden Seiten her vorstehen, um den Führungsstift zu lagern;

wobei die Lichtleiter, die erste und die zweite Platte zum Halten der Lichtleiter und das Flanschelement aneinander befestigt sind, und wobei Lötzinn oder Glas mit niedrigem Schmelzpunkt in den Raum zwischen der unteren und der oberen Platte und zwischen dem Flansch (104) und der Metallhülse (105) eingefügt ist, so dass der Lötzinn oder das Glas mit niedrigem Schmelzpunkt in den Raum im Wesentlichen im gesamten Querschnitt in einer Ebene senkrecht zur Längsrichtung der Lichtleiter (1) eingefüllt ist, und die Lichtleiter (1) zwischen der ersten (41, 101) und der zweiten Platte (42, 102) luftdicht befestigt sind mittels des Lötzinns oder des Glases mit niedrigem Schmelzpunkt, und ebenso die Metallhülse (105) und der Flansch (104).

2. Parallel-Übertragungsmodul nach Anspruch 1, wobei jedes der optischen Übertragungssysteme einzeln optisch mit Lichtleitern in dem Lichtleiterfeld (40) gekoppelt ist und entweder eine optische Vorrichtung (53) zum Aussenden von Licht oder eine optische Vorrichtung zum Empfangen von Licht aufweist, und eine Schaltkreisvorrichtung (52), welche entsprechend der optischen Vorrichtung vorgesehen ist; und wobei die optischen Übertragungssysteme in dem Modulkörper (51) in einem Feld angeordnet sind.

3. Parallel-Übertragungsmodul nach Anspruch 1, wobei der Modulkörper (51) ein Feld von Lichtsendevorrichtungen aufweist, in welchem mehrere Lichtsendevorrichtungen feldartig angeordnet sind, sowie ein Feld mit Lichtempfangsvorrichtungen, in welchem mehrere Lichtempfangsvorrichtungen feldartig angeordnet sind, angeordnet angrenzend an das Feld mit Lichtsendevorrichtungen;

wobei jedes der optischen Übertragungssysteme eine der Lichtsendevorrichtungen aufweist, welche das Feld aus Lichtsendevorrichtungen bilden, und eine der Lichtempfangsvorrichtungen, welche das Feld aus Lichtempfangsvorrichtungen bilden; und

wobei eines der optischen Übertragungssysteme optisch mit jedem Lichtleiter in dem Lichtleiterfeld gekoppelt ist.

4. Parallel-Übertragungsmodul nach Anspruch 1, wobei der Modulkörper (51) ein Wellenleitersubstrat (50) aufweist; und wobei die optischen Übertragungssysteme mehrere optische Wellenleiter sind, welche auf dem Wellenleitersubstrat (50) ausgeformt sind.

5. Parallel-Übertragungsmodul nach Anspruch 1, wobei die Lagerplatten (106) eine kürzere Länge verglichen mit der ersten Platte (101) haben, und wobei das Flanschelement (104) eine Endfläche der Lagerplatte (106) berührt.

6. Parallel-Übertragungsmodul nach Anspruch 1, außerdem mit einem Gehäuse zum Aufnehmen des weiteren optischen Verbinders, welcher gekoppelt werden soll.

7. Parallel-Übertragungsmodul nach Anspruch 1, wobei konvexe Bereiche (112), welche von der ersten Platte (101) in Richtung der Höhe hervorstehen, entlang angrenzender Bereiche zwischen der ersten Platte (101) und den Lagerplatten (106) auf beiden Seiten der ersten Platte (101) ausgeformt sind, wobei diese konvexen Bereiche (112) verhindern, dass das Befestigungsmittel, welches in die

erste Platte eingefüllt ist, ausfließt in die Lagerplatten.

8. Parallel-Übertragungsmodul nach Anspruch 1, weiter mit einem Klemmelement (109) zum Halten und elastischen Pressen des Führungsstifts gegen die Lagerplatte.

9. Parallel-Übertragungsmodul nach Anspruch 1, wobei eine optische Kopplungsendfläche auf der Seite des Lichtleiterfelds mit dem weiteren optischen Verbinden von einer Stelle der Endfläche der Lagerplatte in Längsrichtung der ersten (101) und zweiten Platte (102) hervorsteht.

10. Parallel-Übertragungsmodul nach Anspruch 1, wobei die optische Kopplungsendfläche auf der Seite des Lichtleiterfelds mit dem Modulkörper von einer Stelle der Endfläche des Flansches in Längsrichtung der ersten (101) und zweiten Platte (102) hervorsteht.

11. Parallel-Übertragungsmodul nach Anspruch 1, wobei das Bindemittel Lötzinn ist; und wobei die Lichtleiter (1) zwischen der ersten (101) und der zweiten Platte (102) luftdicht mittels des Lötzinns befestigt sind.

12. Parallel-Übertragungsmodul nach Anspruch 11, wobei der Lötzinn eine Legierung aus Pb und Sn ist; und wobei der Lötzinn ein Additiv aufweist, welches aus der Gruppe Zn, Sb, Al, Ti, Si und Cu ausgewählt ist.

13. Parallel-Übertragungsmodul nach Anspruch 12, wobei die Lichtleiter (1) kohlenstoff-ummantelte Fasern sind.

14. Parallel-Übertragungsmodul nach Anspruch 1, weiter mit einer Hülse (110), welche an den Außenseiten der ersten (101) und der zweiten Platte (102) vorgesehen ist, um die Lichtleiter (1) zu halten.

15. Parallel-Übertragungsmodul nach Anspruch 14, wobei die Hülse (110) aus einer Ni-Fe-Bernsteinlegierung besteht.

16. Parallel-Übertragungsmodul nach Anspruch 1, wobei die erste Platte (101) und die zweite Platte (102) durch Anodenkopplung miteinander verbunden sind.

17. Parallel-Übertragungsmodul nach Anspruch 1, wobei die Lichtleiter (1), welche in der optischen Kopplungsendfläche feldartig angeordnet sind, einen Modusfelddurchmesser haben, welcher in der Nähe der optischen Kopplungsendfläche teilweise vergrößert ist.

18. Parallel-Übertragungsmodul nach Anspruch 17, wobei der Modusfelddurchmesser vergrößert ist durch Konzentrieren von verbleibender Belastung in einem Kernbereich, um einen Brechindex des Kernbereichs zu senken; und wobei der Modusfelddurchmesser um zumindest 20% erhöht ist verglichen mit einem Fall, in welchem die verbleibende Belastung entfernt ist.

19. Verfahren zur Herstellung eines Parallel-Übertragungsmoduls mit:

einem ersten Schritt des Positionierens eines Lichtleiters (1) in jede Positioniernut (101a) in einer ersten Platte (101) mit mehreren solcher Positioniernuten (101a), und des Pressens aller Lichtleiter (1) in die Positioniernuten mittels einer zweiten Platte (102);

einem zweiten Schritt des Anordnens eines Flanschelements (104) an den Außenseiten der ersten (101) und der zweiten Platte (102), welche alle Lichtleiter (1) halten;

einem dritten Schritt des Eintauchens einer der Endflächen der ersten (101) und der zweiten Platte (102), wo die Endflächen der Lichtleiter (1) angeordnet sind, in ein Lötbad, welches mit Lötzinn oder mit Glas mit niedrigem Schmelzpunkt gefüllt ist, um das Flanschelement (104) an den Außenseiten der ersten (101) und der zweiten Platte (102) zu befestigen;

einem vierten Schritt des Einfüllens von Lötzinn des Lötbad in eine Lücke zwischen der ersten und der zweiten Platte von einem Ende zum anderen Ende für eine luftdichte Abdichtung zwischen der ersten und der zweiten Platte und den Lichtleitern, und wobei Lötzinn oder Glas mit niedrigem Schmelzpunkt in den Raum zwischen der oberen und der unteren Platte und zwischen dem Flansch (104) und der Metallhülse (105) eingefüllt wird, so dass der Lötzinn oder das Glas mit niedrigem Schmelzpunkt in den Raum im Wesentlichen im gesamten Querschnitt in einer Ebene senkrecht zu einer Längsrichtung der Lichtleiter (1) eingefüllt wird, und wobei die Lichtleiter (1) zwischen der ersten (41, 101) und der zweiten Platte (42, 102) befestigt werden, wobei der vierte Schritt gleichzeitig mit dem dritten Schritt oder direkt vor oder nach dem dritten Schritt ausgeführt wird;

einem fünften Schritt des Polierens beider Endflächen der ersten (101) und der zweiten Platte (102), um die Endflächen aller Lichtleiter spiegelartig zu gestalten, wodurch ein Lichtleiter-

feld ausgeformt wird; und

einem sechsten Schritt des Befestigens einer Endfläche des Lichtleiterfelds an einer optischen Kopplungsendfläche eines Modulkörpers mit mehreren optischen Übertragungssystemen, um das Lichtleiterfeld und den Modulkörper zu einem einzigen Körper zu machen, und des optischen Koppeln der Lichtleiter in dem Lichtleiterfeld einzeln mit den optischen Übertragungssystemen in dem Modulkörper.

20. Verfahren zur Herstellung eines Parallel-Übertragungsmoduls nach Anspruch 19, wobei in dem vierten Schritt Ultraschallschwingung verwendet wird, um den Lötzinn oder das Glas mit niedrigem Schmelzpunkt in die erste und die zweite Platte von einem Ende zum anderen einzufüllen.

Revendications

1. Module (M) de transmission en parallèle qui transmet plusieurs signaux électriques en parallèle, le module de transmission en parallèle comprenant :

un corps de module (51) qui comporte plusieurs systèmes de transmission optique (52, 53, 54) destinés à transmettre séparément des signaux optiques, un arrangement (40) de fibres optiques placé à une première extrémité des systèmes de transmission optique (52, 53, 54), disposé et fixé dans le corps de module (51), et comprenant plusieurs fibres optiques destinées à être couplées optiquement et individuellement aux systèmes de transmission optique, et un dispositif (45) de guidage d'un autre connecteur optique destiné à être couplé à une face d'extrémité de couplage optique de l'arrangement de fibres optiques (40), la face d'extrémité de couplage optique étant disposée du côté opposé à la face d'extrémité couplée optiquement aux systèmes de transmission optique,

dans lequel le dispositif de guidage est choisi parmi une broche de guidage destinée à positionner l'autre connecteur optique afin qu'il soit couplé à la face d'extrémité de couplage optique de l'arrangement de fibres optiques (40), et une gorge de guidage (45) destinée à loger une broche de guidage placée sur l'autre connecteur optique afin qu'il soit couplé à la face d'extrémité de couplage optique de l'arrangement de fibres optiques, et

dans lequel un organe à flasque (104) est placé aux périphéries de la première (41) et de la seconde plaque (42),

caractérisé en ce que

l'arrangement de fibres optiques (40) comprend

- une première plaque (41, 101) qui comporte plusieurs gorges de positionnement (43, 101a) destinées au positionnement des fibres optiques, 5
- une seconde plaque (42, 102) destinée à exercer une pression contre chaque fibre optique disposée dans chaque gorge de positionnement (43, 101a) formée sur la première plaque (41, 101) dans les gorges de positionnement (43, 101a), et 10
- des plaques de support (106) disposées des deux côtés en direction transversale à la première plaque (41, 101) afin qu'elles dépassent des deux côtés pour supporter la broche de guidage, 15

dans lequel les fibres optiques, la première et la seconde plaque destinées à retenir les fibres optiques, et l'organe à flasque sont fixés mutuellement, et dans lequel de la soudure ou un verre à faible température de fusion est inséré dans l'espace formé entre les plaques inférieure et supérieure et entre le flasque (104) et le manchon métallique (105) afin que la soudure ou le verre à faible température de fusion remplisse l'espace pratiquement dans toute la section dans un plan perpendiculaire à une direction longitudinale des fibres optiques (1), et les fibres optiques (1) sont fixées entre la première plaque (41, 101) et la seconde plaque (42, 102) de manière hermétique par la soudure ou le verre à faible température de fusion, comme le manchon métallique (105) et le flasque (104). 20

2. Module de transmission en parallèle selon la revendication 1, dans lequel chacun des systèmes de transmission optique est couplé optiquement individuellement aux fibres optiques de l'arrangement de fibres optiques (40) et comporte un dispositif choisi parmi un dispositif optique (53) destiné à émettre de la lumière et un dispositif optique destiné à recevoir de la lumière, et un dispositif à circuit (52) disposé afin qu'il corresponde au dispositif optique, et les systèmes de transmission optique sont placés dans le corps de module (51) sous forme d'un arrangement. 25
3. Module de transmission en parallèle selon la revendication 1, dans lequel le corps de module (51) comporte un arrangement de dispositifs photo-émissifs comprenant plusieurs dispositifs photo-émissifs convenablement arrangés, et un arrangement de dispositifs photorécepteurs comprenant plusieurs dispositifs photorécepteurs disposés suivant un arrangement, adjacent à l'arrangement des dispositifs photo-émissifs, 30

dans lequel chaque système de transmission optique comporte l'un des dispositifs photo-émissifs constituant l'arrangement de dispositifs photo-émissifs et l'un des dispositifs photorécepteurs constituant l'arrangement des dispositifs photorécepteurs, et dans lequel l'un des systèmes de transmission optique est couplé optiquement à chaque fibre optique de l'arrangement de fibres optiques.

4. Module de transmission en parallèle selon la revendication 1, dans lequel le corps de module (51) comporte un substrat de guide d'onde (50), et les systèmes de transmission optique sont sous forme de plusieurs guides d'onde optiques formés sur le substrat de guide d'onde (50). 35
5. Module de transmission en parallèle selon la revendication 1, dans lequel les plaques de support (106) ont une longueur inférieure à celle de la première plaque (101), et l'organe à flasque (104) touche une première face d'extrémité de la plaque de support (106). 40
6. Module de transmission en parallèle selon la revendication 1, comprenant en outre un boîtier destiné à supporter l'autre connecteur optique à coupler. 45
7. Module de transmission en parallèle selon la revendication 1, dans lequel des parties convexes (112) qui dépassent de la première plaque (101) dans la direction de la hauteur sont formées avec des régions adjacentes entre la première plaque (101) et les plaques de support (106) des deux côtés de la première plaque (101), et les parties convexes (112) empêchent l'écoulement vers l'extérieur de l'agent de fixation chargé dans la première plaque à l'intérieur des plaques de support. 50
8. Module de transmission en parallèle selon la revendication 1, comprenant en outre un organe à pince (109) destiné à maintenir la broche de guidage contre la plaque de support et à exercer une pression élastique contre cette broche. 55
9. Module de transmission en parallèle selon la revendication 1, dans lequel une face d'extrémité de couplage optique du côté de l'autre connecteur optique de l'arrangement de fibres optiques dépasse d'une position de la face d'extrémité de la plaque de support dans la direction longitudinale de la première plaque (101) et de la seconde plaque (102).
10. Module de transmission en parallèle selon la revendication 1, dans lequel la face d'extrémité de couplage optique du côté du corps du module de l'arrangement de fibres optiques dépasse d'une position de la face d'extrémité du flasque dans la direc-

tion longitudinale de la première plaque (101) et de la seconde plaque (102).

11. Module de transmission en parallèle selon la revendication 1, dans lequel l'agent de fixation est de la soudure, et les fibres optiques (1) sont fixées entre la première plaque (101) et la seconde plaque (102) de manière hermétique par la soudure. 5
12. Module de transmission en parallèle selon la revendication 11, dans lequel la soudure est formée d'alliage Pb-Sn, et la soudure comporte un type d'adjuvant choisi dans le groupe formé par Zn, Sb, Al, Ti, Si et Cu. 10
13. Module de transmission en parallèle selon la revendication 12, dans lequel les fibres optiques (1) sont des fibres revêtues de carbone. 15
14. Module de transmission en parallèle selon la revendication 1, comprenant en outre un manchon (110) disposé aux périphéries de la première plaque (101) et de la seconde plaque (102) pour le maintien des fibres optiques (1). 20
15. Module de transmission en parallèle selon la revendication 14, dans lequel le manchon (110) est formé d'alliage "ambre" de Ni-Fe. 25
16. Module de transmission en parallèle selon la revendication 1, dans lequel la première plaque (101) et la seconde plaque (102) sont liées mutuellement par couplage anodique. 30
17. Module de transmission en parallèle selon la revendication 1, dans lequel les fibres optiques (1) formant l'arrangement à la face d'extrémité de couplage optique ont un diamètre de champ de mode partiellement agrandi au voisinage de la face d'extrémité de couplage optique. 35
18. Module de transmission en parallèle selon la revendication 17, dans lequel le diamètre du champ de mode est agrandi par concentration de la contrainte résiduelle dans une région d'âme afin que l'indice de réfraction de la région d'âme soit réduit, et le diamètre du champ de mode est agrandi de 20 % ou plus par rapport au cas où la contrainte résiduelle est supprimée. 40
19. Procédé de fabrication d'un module de transmission en parallèle, comprenant : 45

une première étape de positionnement d'une fibre optique (1) dans chaque gorge de positionnement (101a) formée dans une première plaque (101) ayant plusieurs gorges de positionnement (101a), et d'application d'une pression

sur toutes les fibres optiques (1) vers les gorges de positionnement à l'aide d'une seconde plaque (102),

une seconde étape de disposition d'un organe à flasque (104) aux périphéries de la première plaque (101) et de la seconde plaque (102) avec maintien de toutes les fibres optiques (1), une troisième étape d'imprégnation de l'une des faces d'extrémité de la première plaque (101) et de la seconde plaque (102), auxquelles faces d'extrémité sont disposées les fibres optiques (1), dans un bain de soudure contenant de la soudure ou un verre à faible température de fusion afin que l'organe à flasque (104) soit fixé aux périphéries de la première plaque (101) et de la seconde plaque (102), une quatrième étape de remplissage, par de la soudure du bain de soudure, d'un espace formé entre la première et la seconde plaque depuis une première extrémité vers l'autre extrémité pour assurer le scellement hermétique entre la première et la seconde plaque et les fibres optiques, et dans laquelle de la soudure ou un verre à faible température de fusion est inséré dans l'espace formé entre la plaque inférieure et la plaque supérieure et entre le flasque (104) et le manchon métallique (105) afin que la soudure ou le verre à faible température de fusion remplisse l'espace pratiquement dans toute la section dans un plan perpendiculaire à la direction longitudinale des fibres optiques (1), et les fibres optiques (1) sont fixées entre la première plaque (101) et la seconde plaque (102), une quatrième étape étant exécutée en même temps que la troisième étape et juste avant ou après la troisième étape, une cinquième étape de polissage des faces d'extrémité de la première plaque (101) et de la seconde plaque (102) pour que les faces d'extrémité de toutes les fibres optiques aient un état spéculaire, si bien qu'un arrangement de fibres optiques est réalisé, et une sixième étape de fixation d'une première face d'extrémité de l'arrangement de fibres optiques à une face d'extrémité de couplage optique d'un corps de module comprenant plusieurs systèmes de transmission optique afin que l'arrangement de fibres optiques et le corps de module forment un seul corps, et le couplage optique des fibres optiques de l'arrangement de fibres optiques individuellement avec les systèmes de transmission optique dans le corps de module.

20. Procédé de fabrication d'un module de transmission en parallèle selon la revendication 19, dans lequel, au cours de la quatrième étape, une oscillation ultrasonore est utilisée pour le remplissage par la

soudure ou le verre à faible température de fusion
des première et seconde plaques d'une première
extrémité à l'autre extrémité.

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Fig. 1

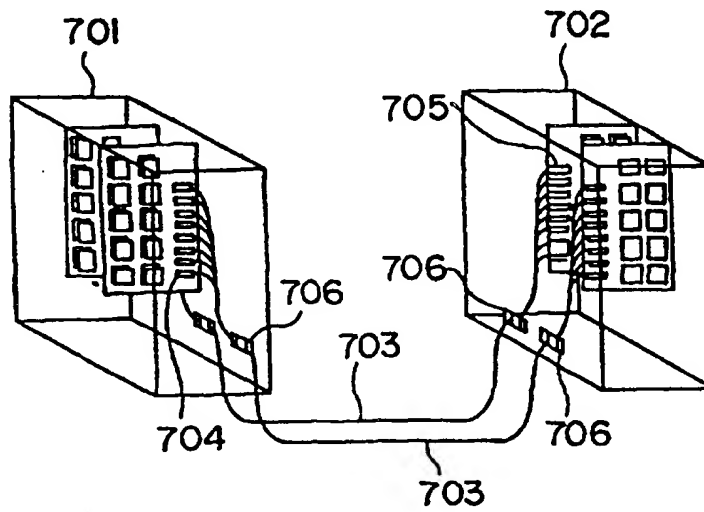


Fig. 2

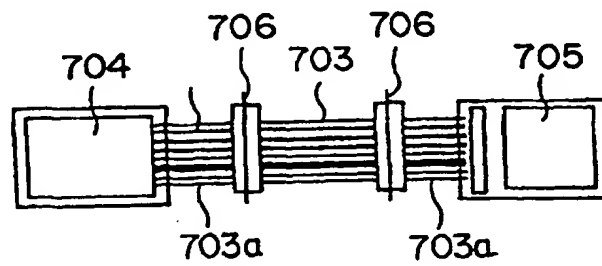


Fig. 3

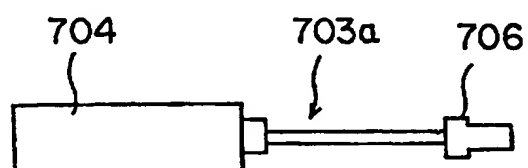
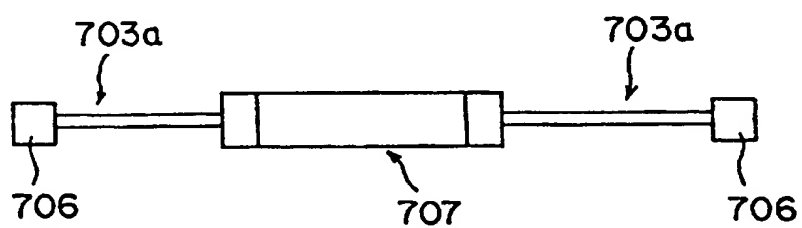


Fig. 4



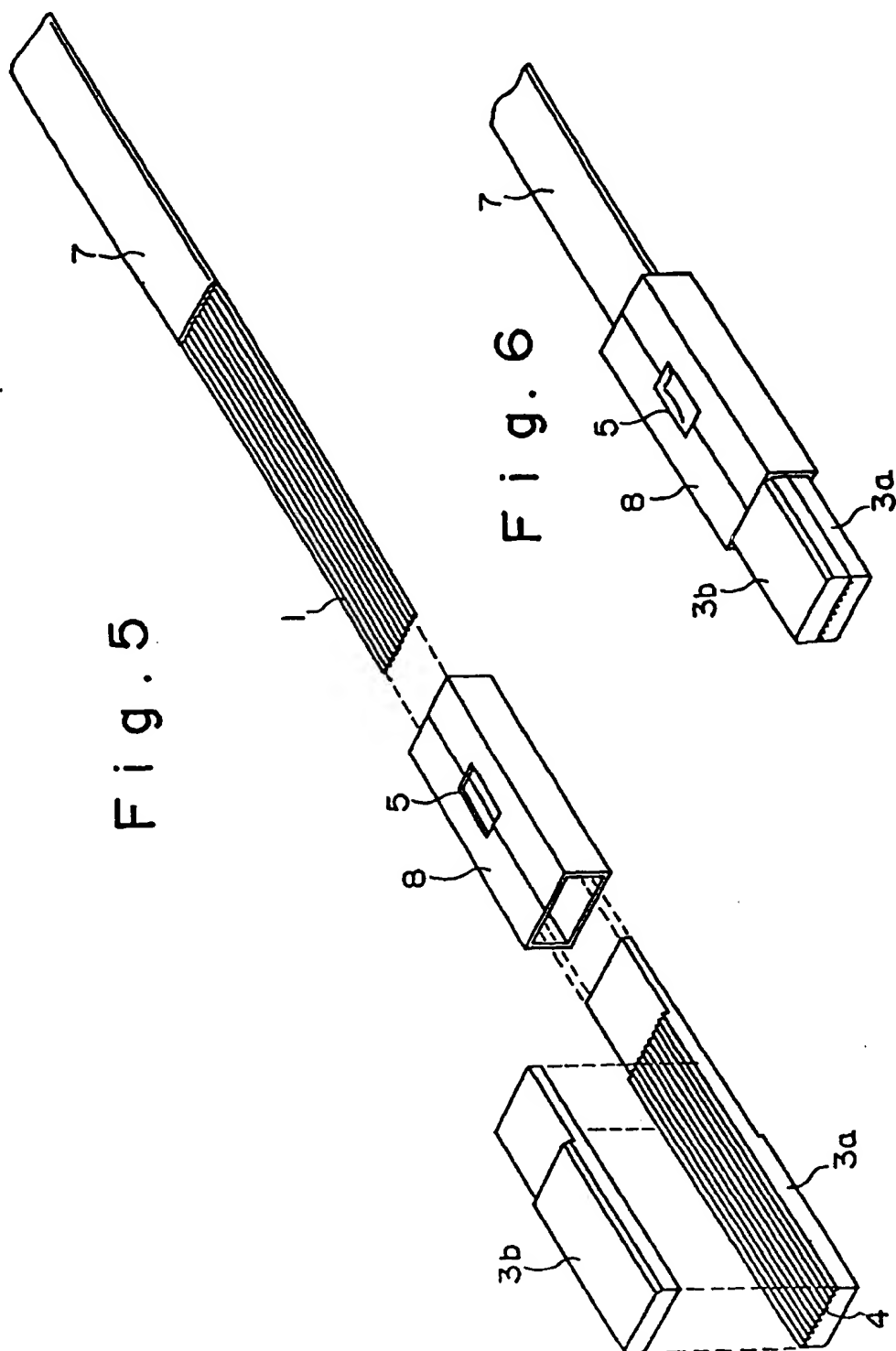


Fig. 7

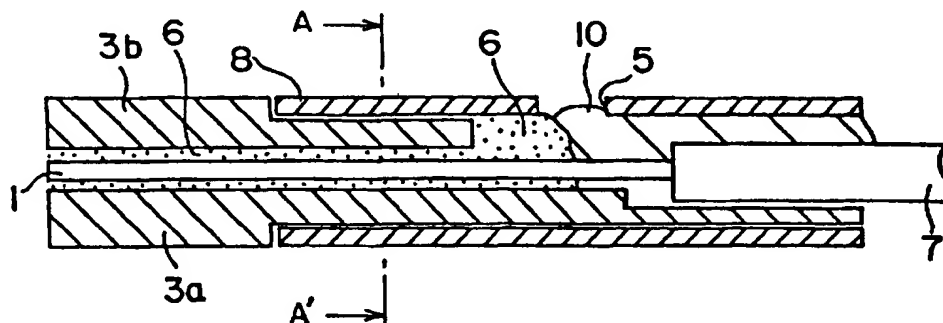


Fig. 8

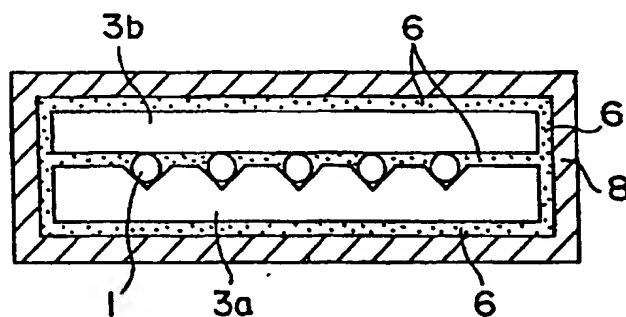


Fig. 9

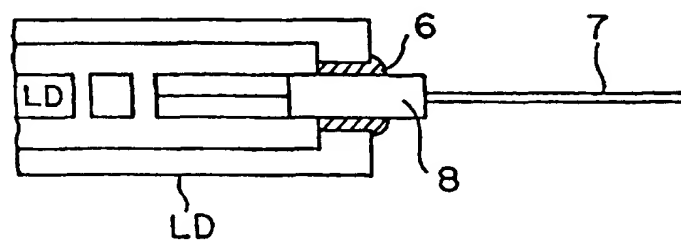


Fig.10A

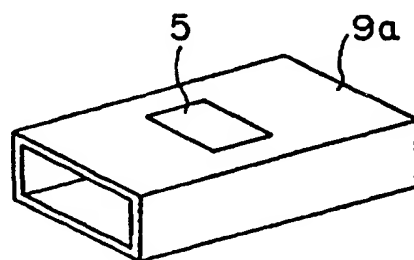


Fig.10B

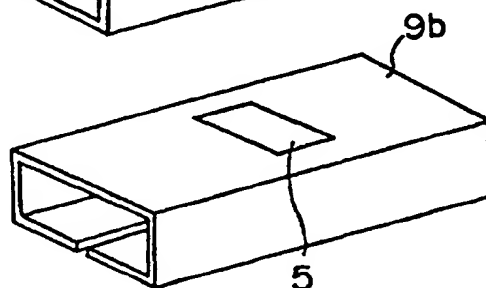


Fig.11

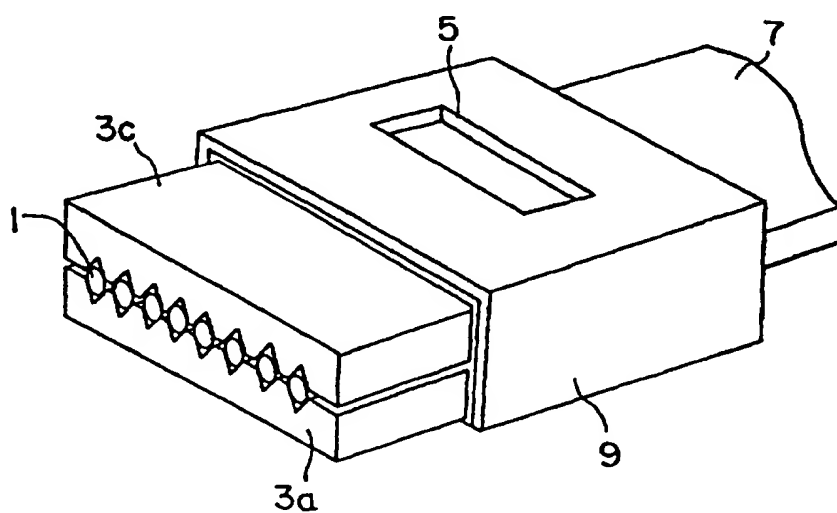


Fig.12A

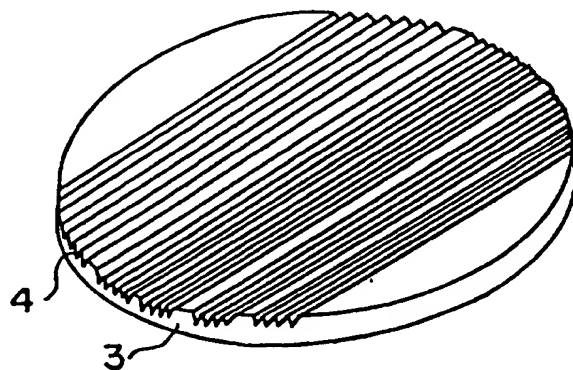


Fig.12B

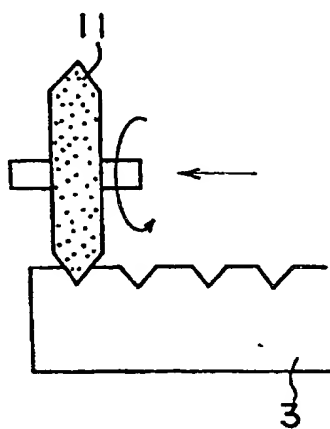


Fig.12C

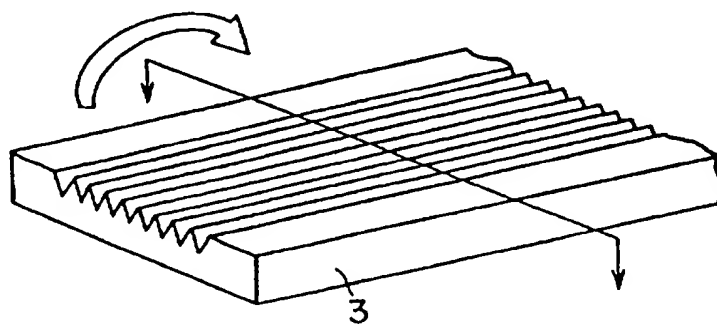


Fig. 13

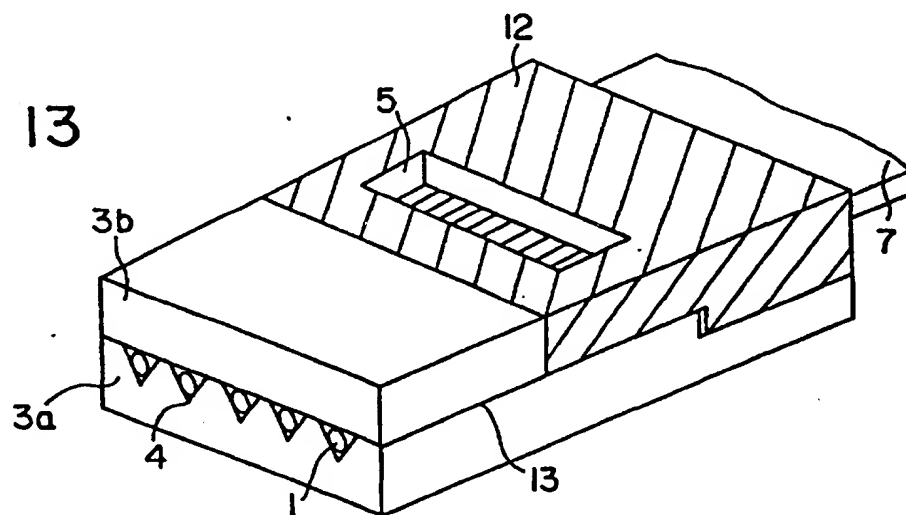


Fig. 14A

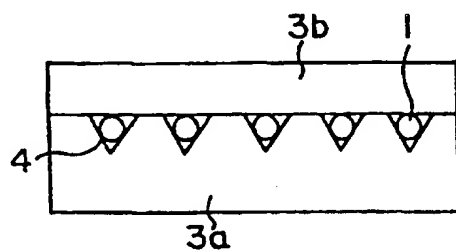


Fig. 14B

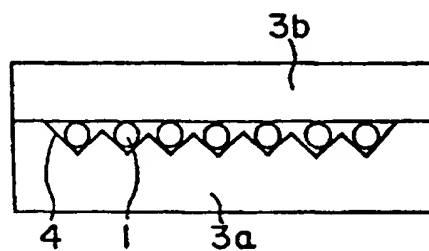


Fig. 14C

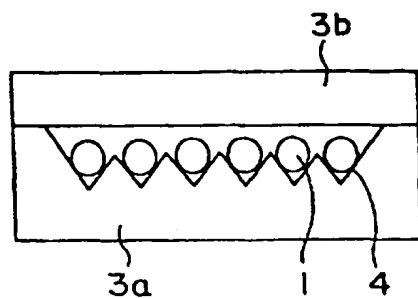


Fig. 14D

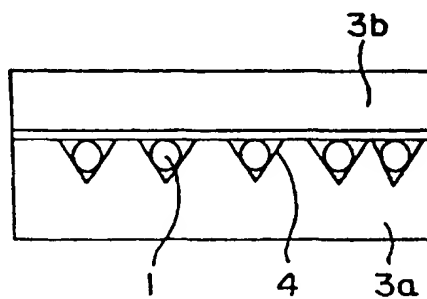


Fig.15A

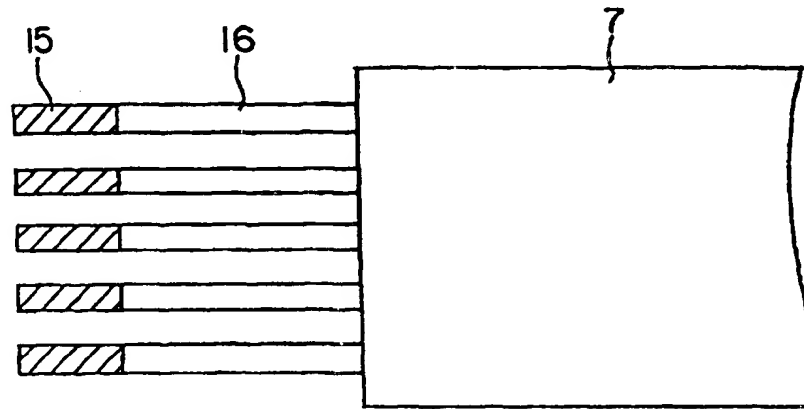


Fig.15B

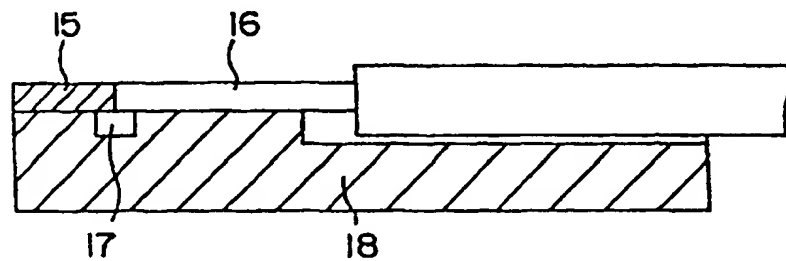


Fig. 16A

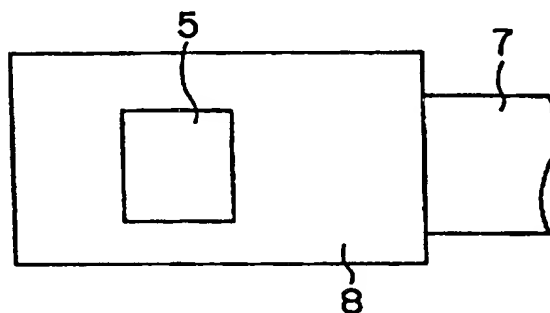


Fig. 16B

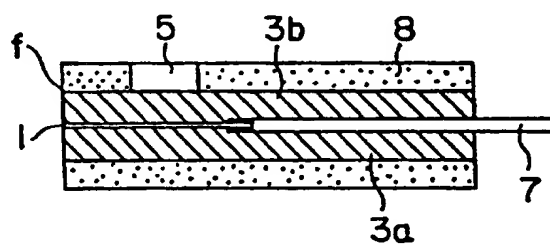


Fig. 16C

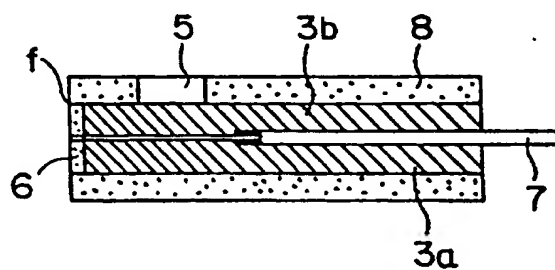


Fig. 17

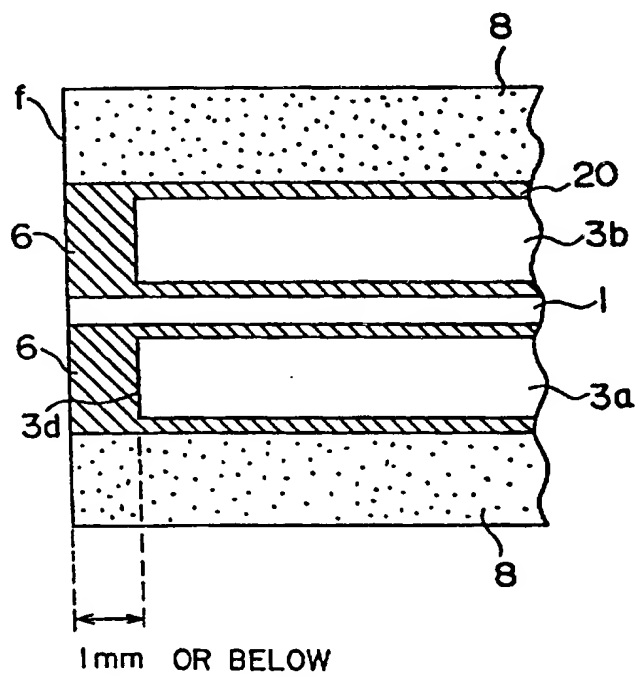


Fig.18A

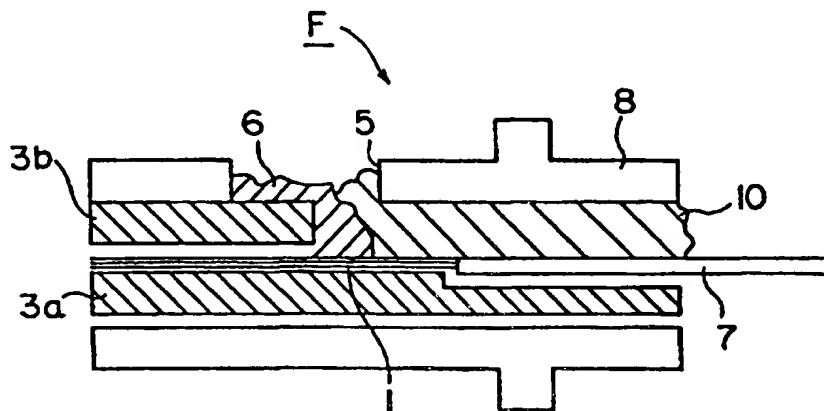


Fig.18B

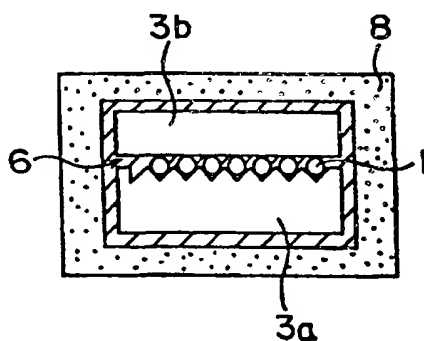


Fig.18C

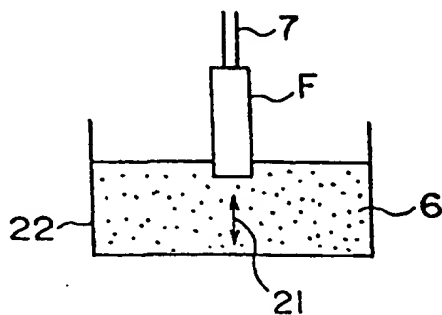


Fig.19A

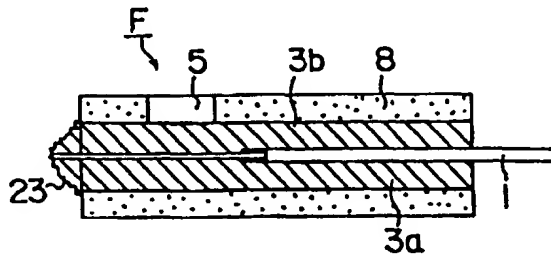


Fig.19B

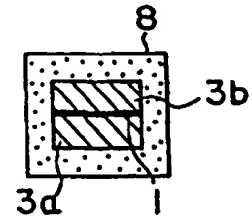


Fig. 20

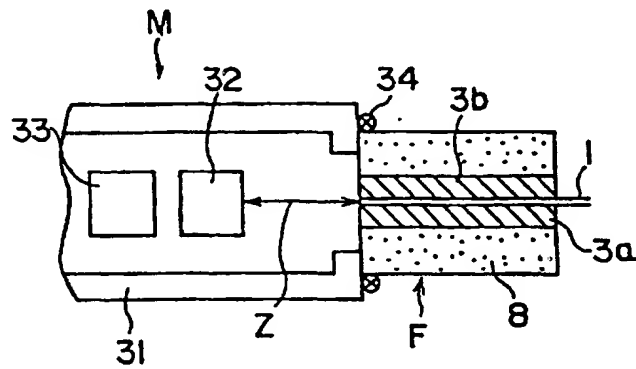


Fig. 21

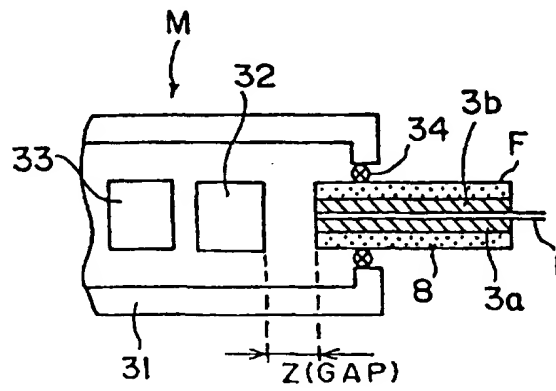


Fig. 22A

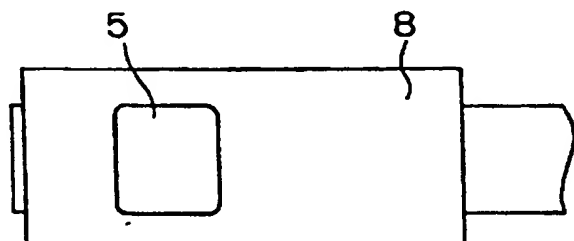


Fig. 22B

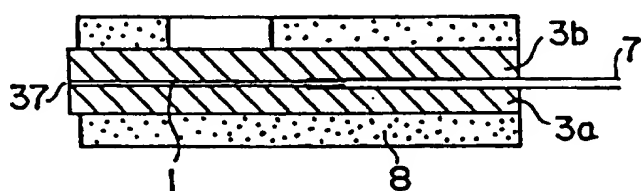


Fig. 22C

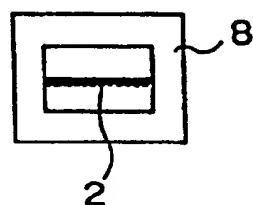


Fig. 23A

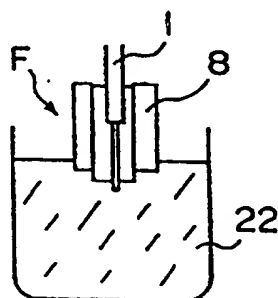


Fig. 23B

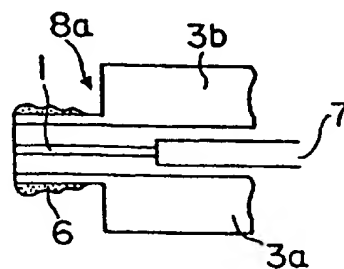


Fig.24A

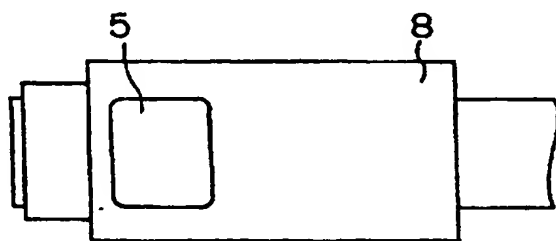


Fig.24B

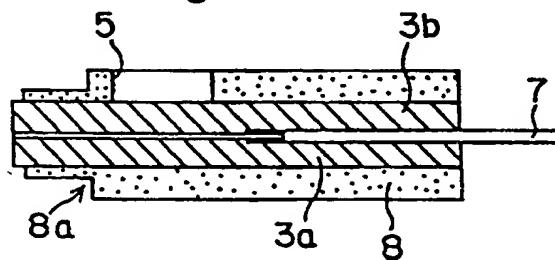
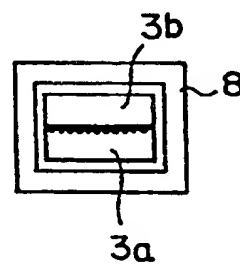


Fig.24C



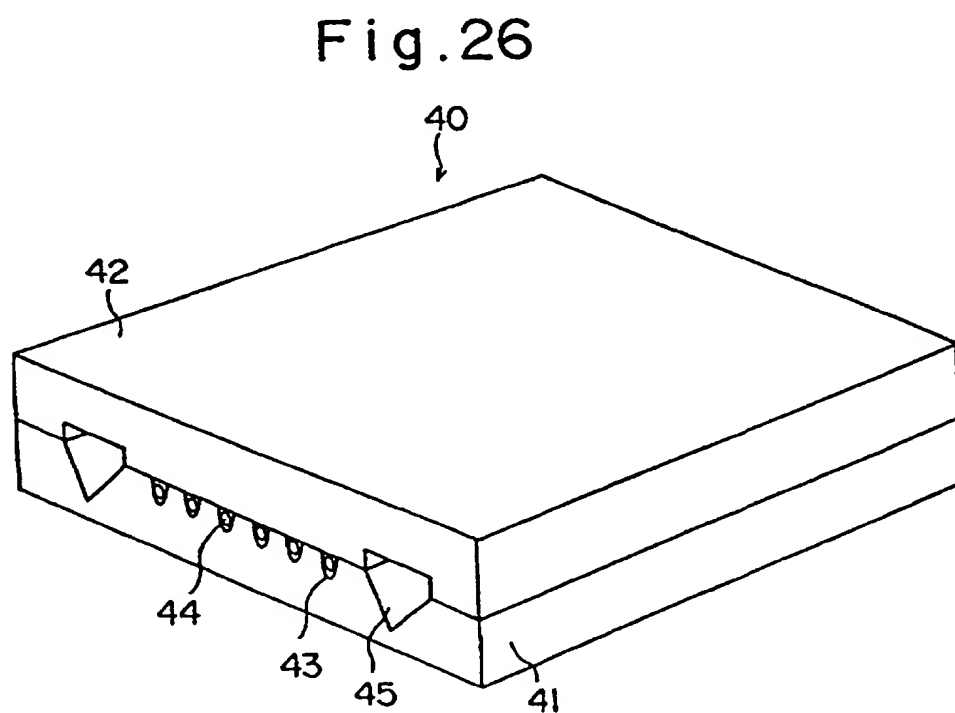
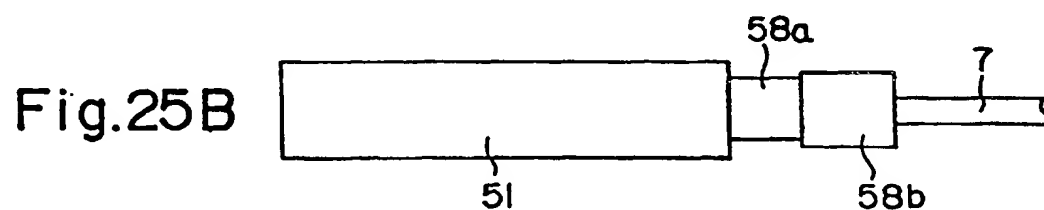
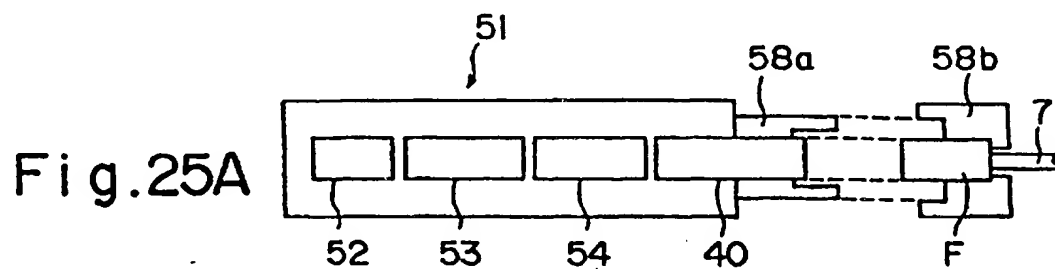


Fig.27A

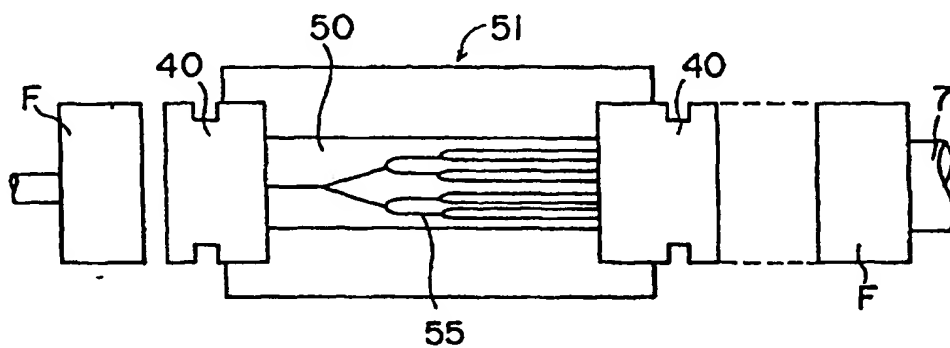


Fig.27B

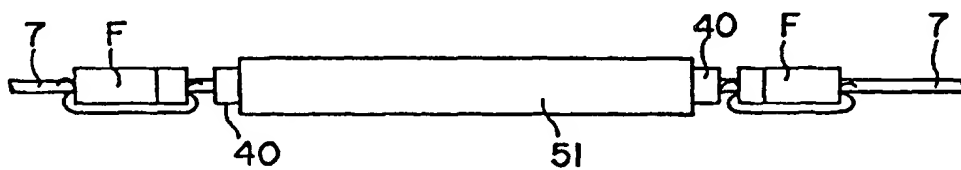


Fig. 28

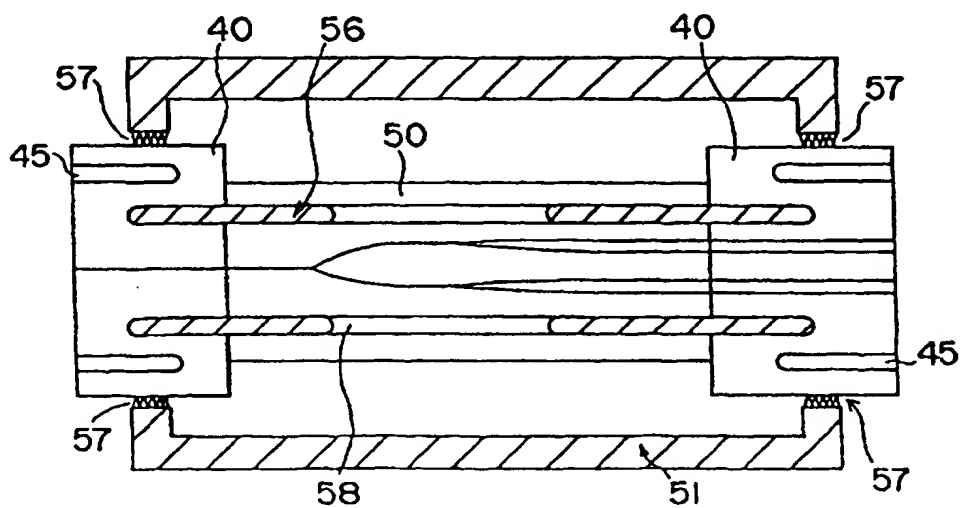


Fig.29A

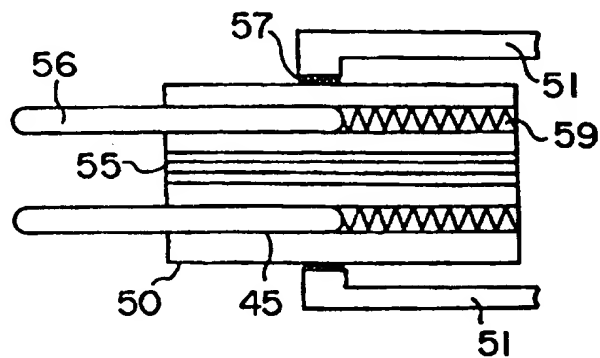


Fig.29B

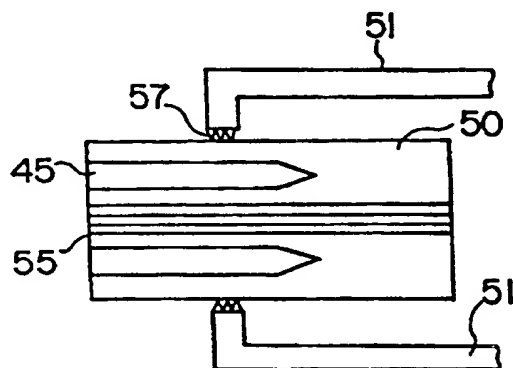


Fig.29C

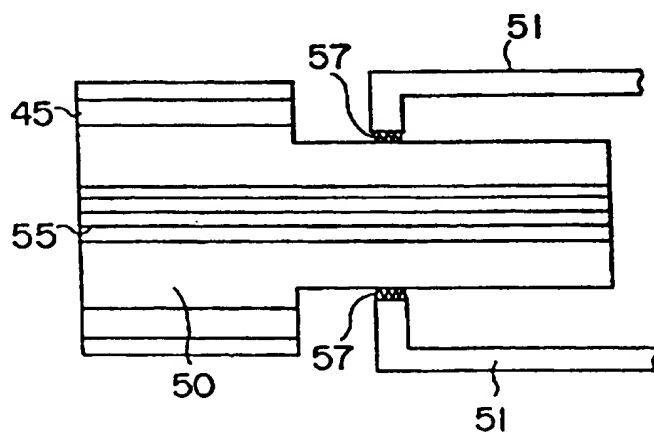


Fig. 30A

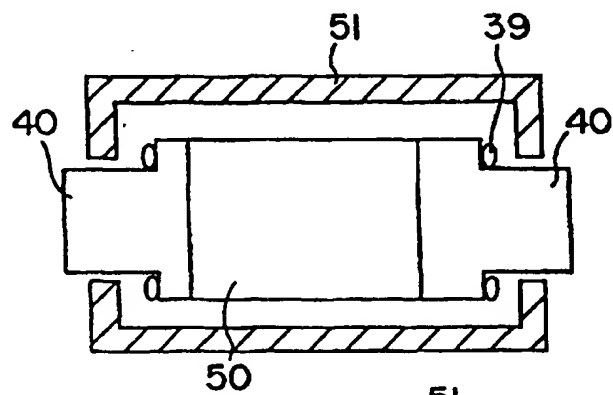


Fig. 30B

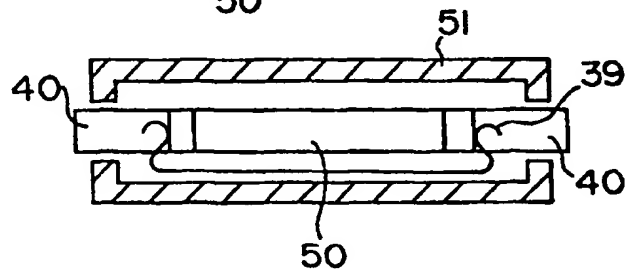


Fig.31

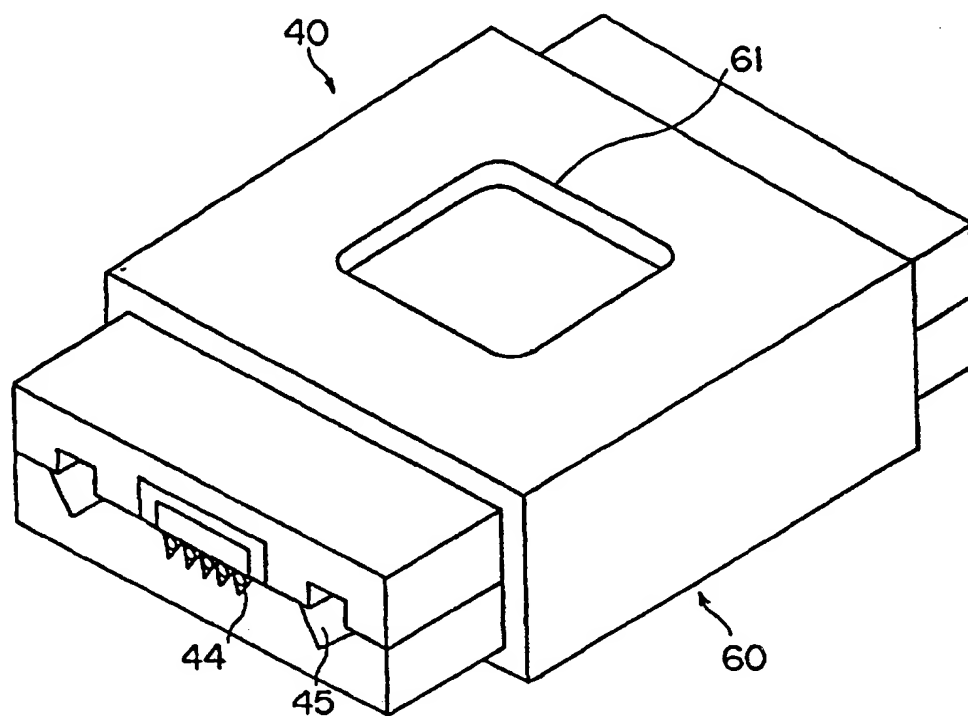


Fig.32

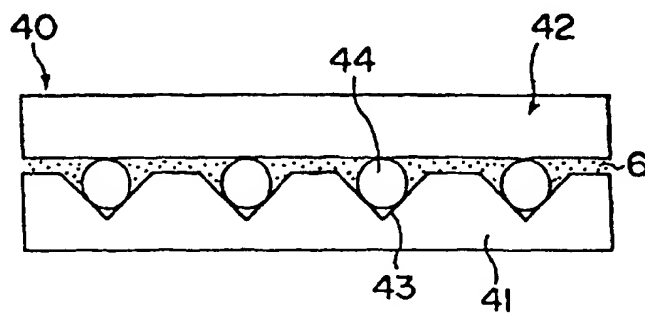


Fig. 33

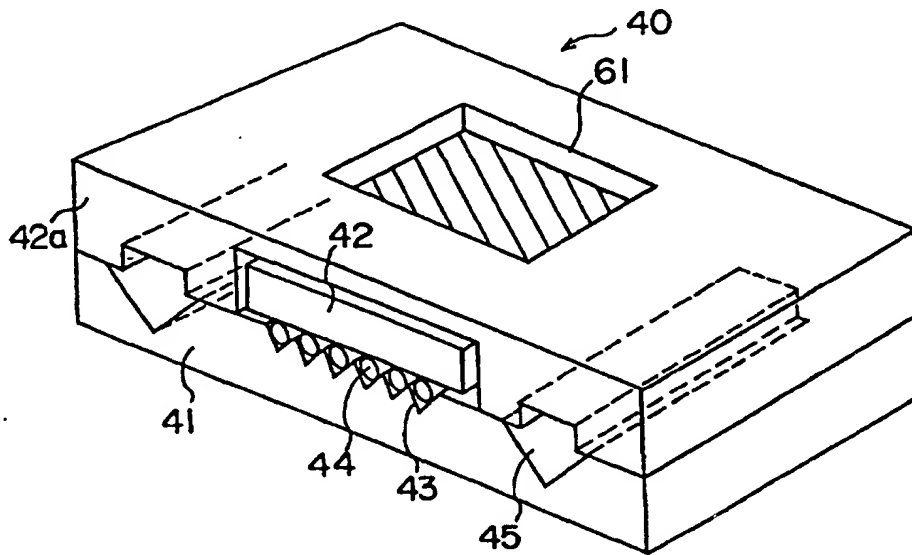


Fig. 34

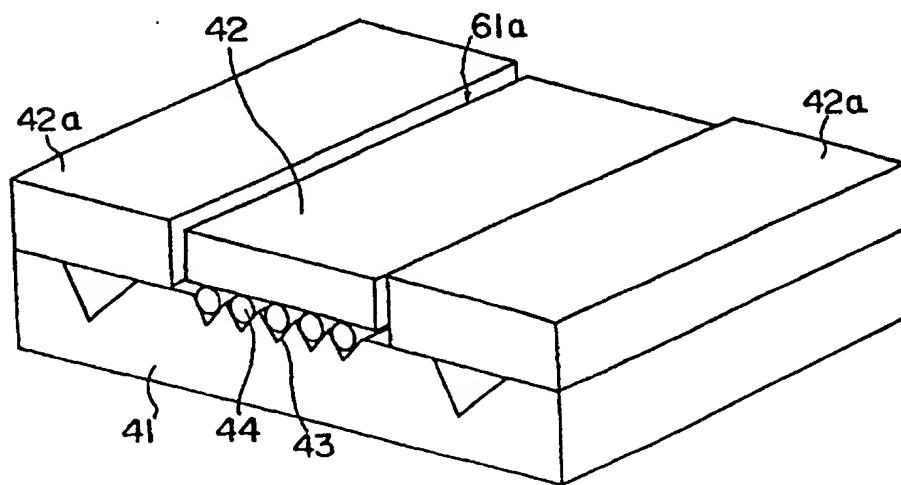


Fig.35A

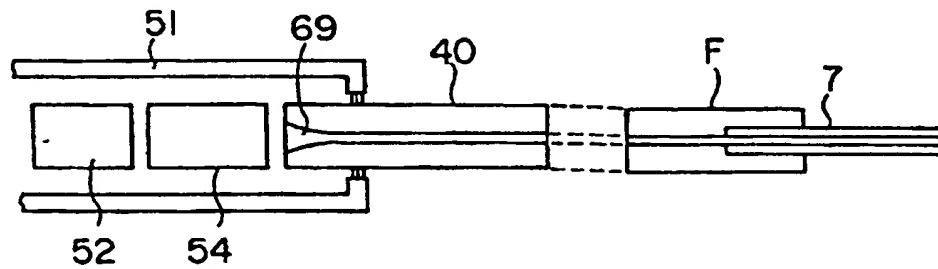


Fig.35B

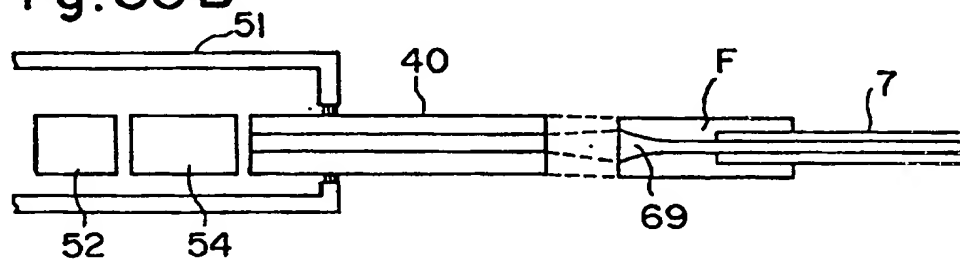


Fig.35C

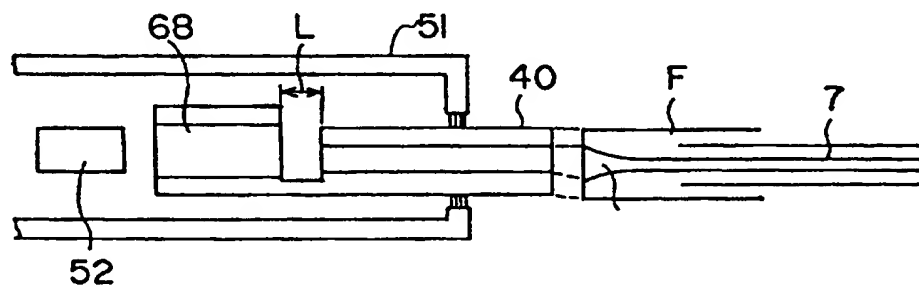


Fig.35D

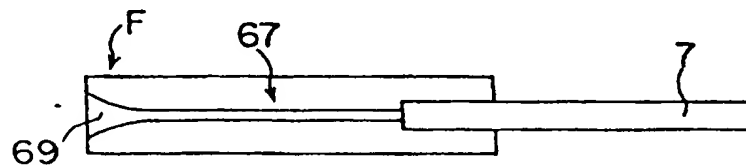


Fig.36A

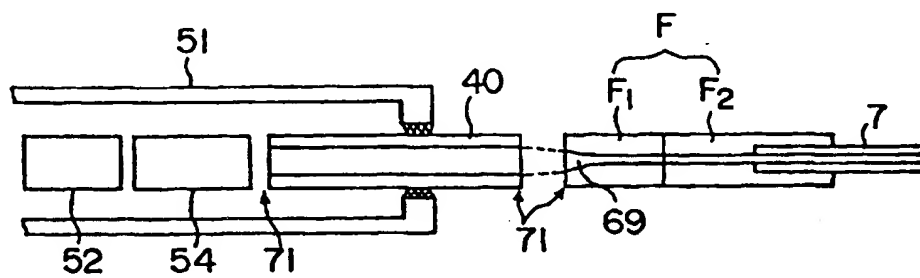


Fig.36B

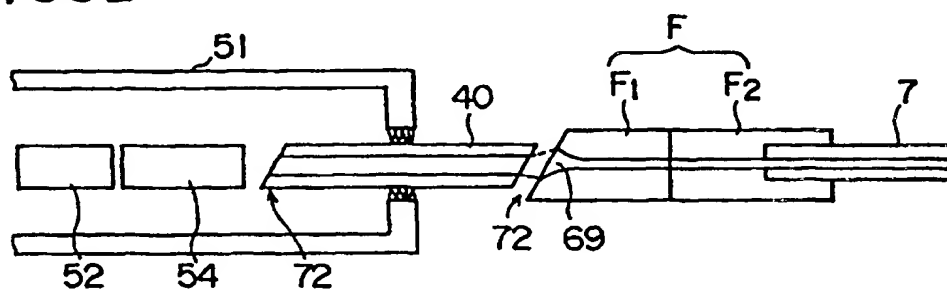


Fig.37

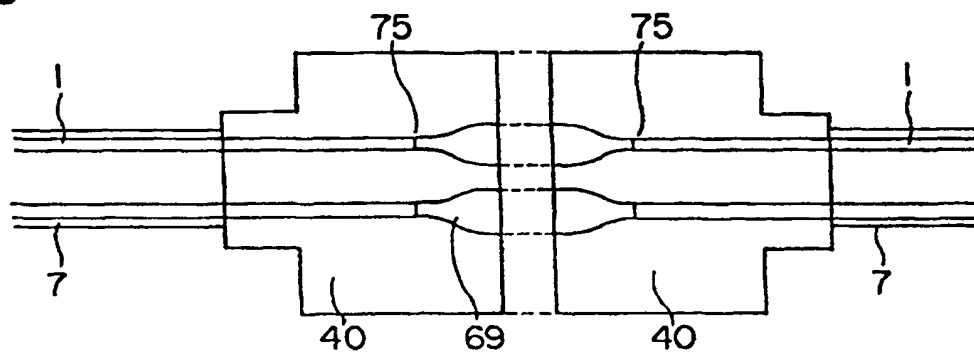


Fig. 38

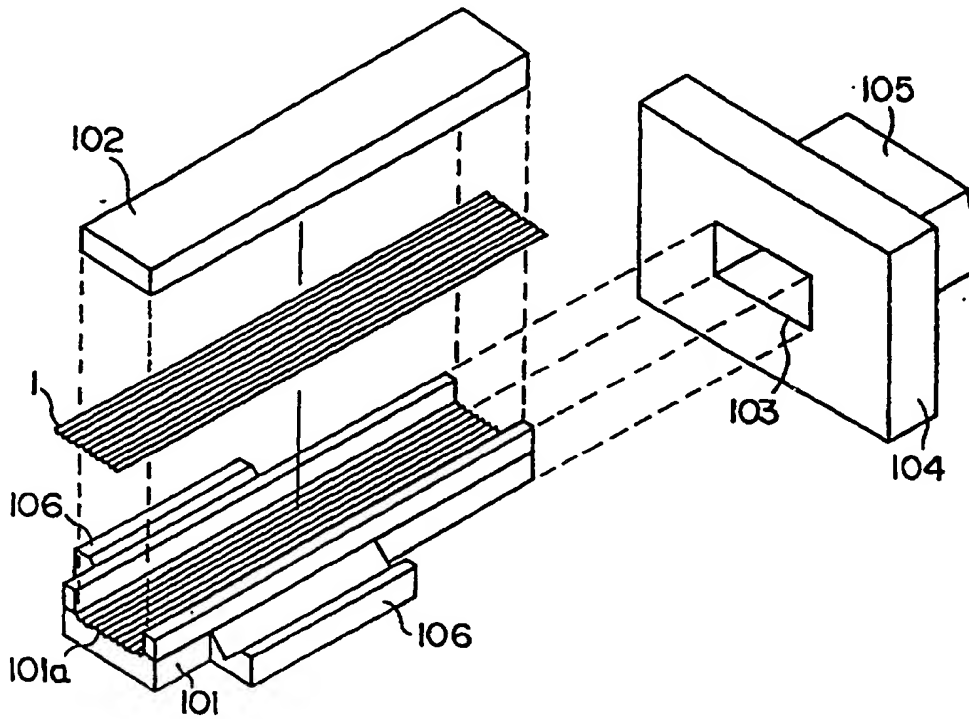


Fig. 39

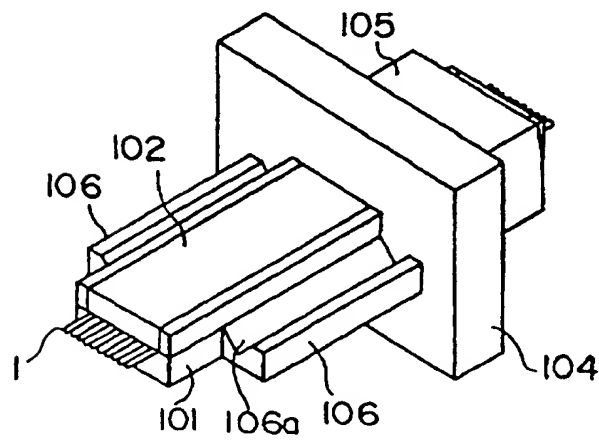


Fig. 40

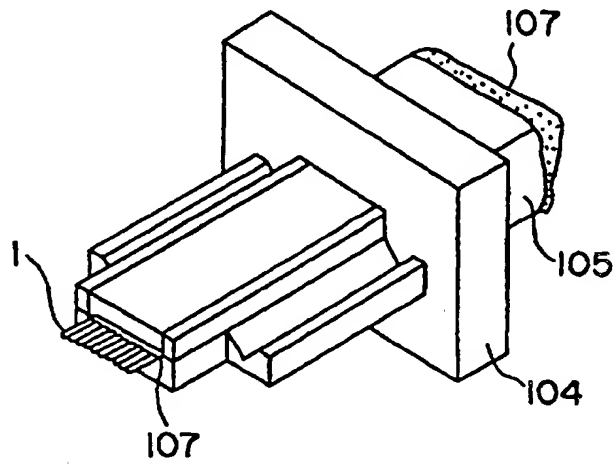


Fig. 41

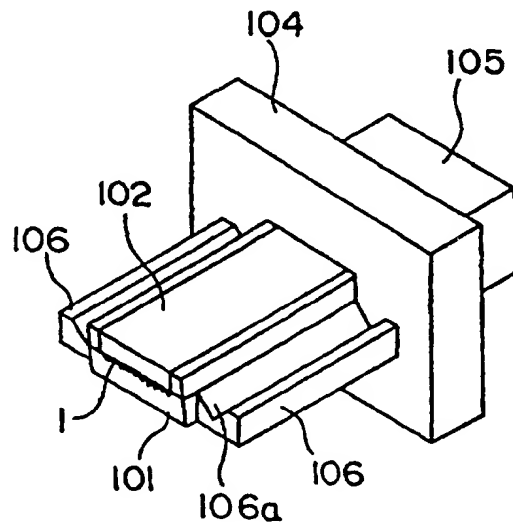


Fig. 42

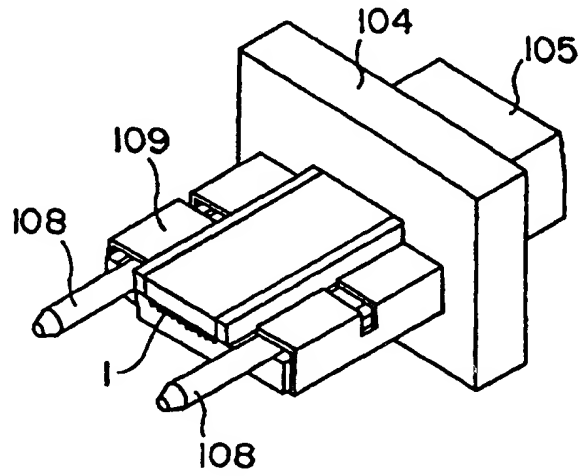


Fig. 43

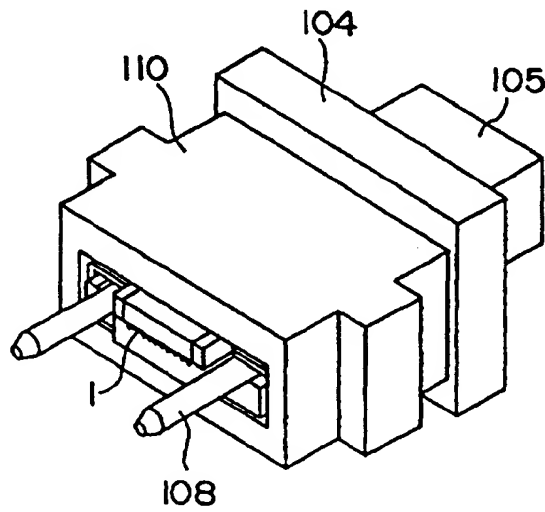


Fig. 44C

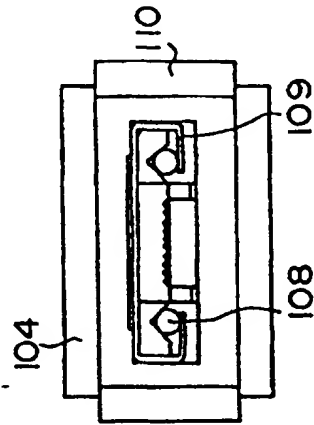


Fig. 44A

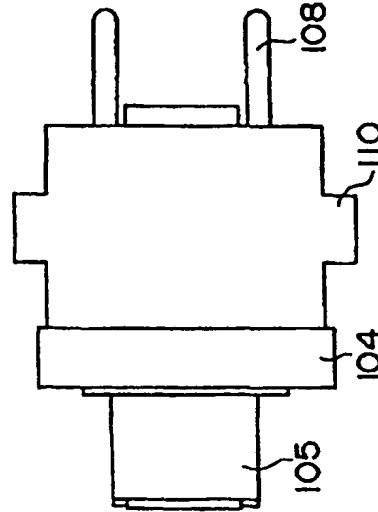
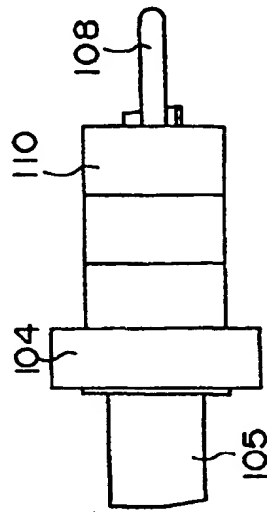


Fig. 44B

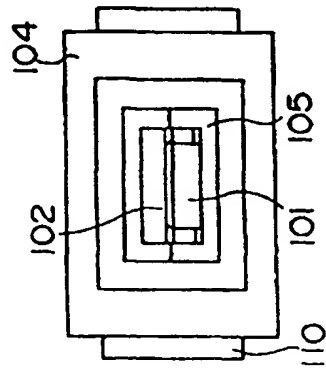


Fig. 44D

Fig. 45

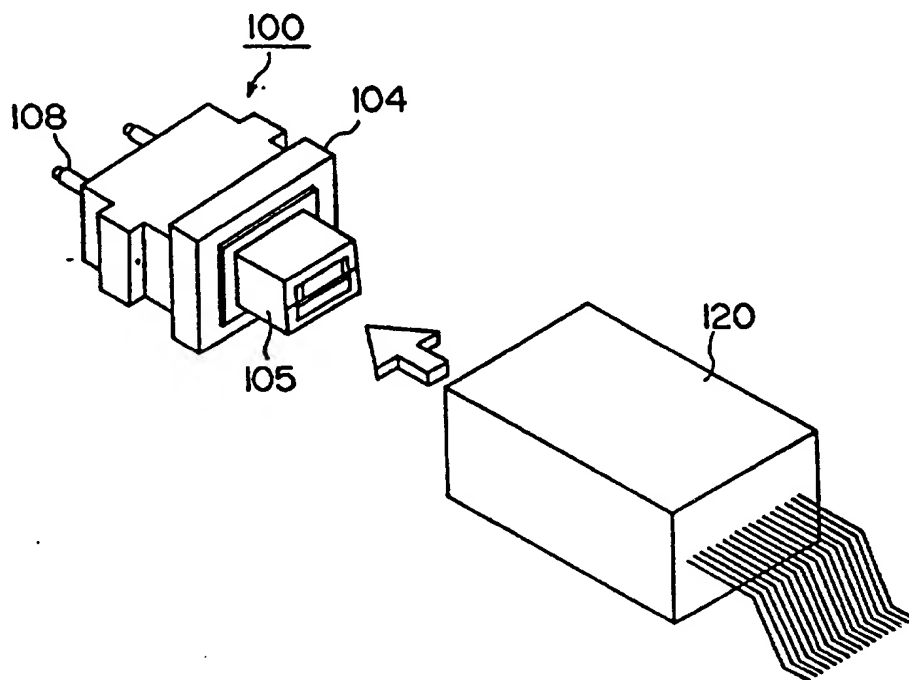


Fig. 46

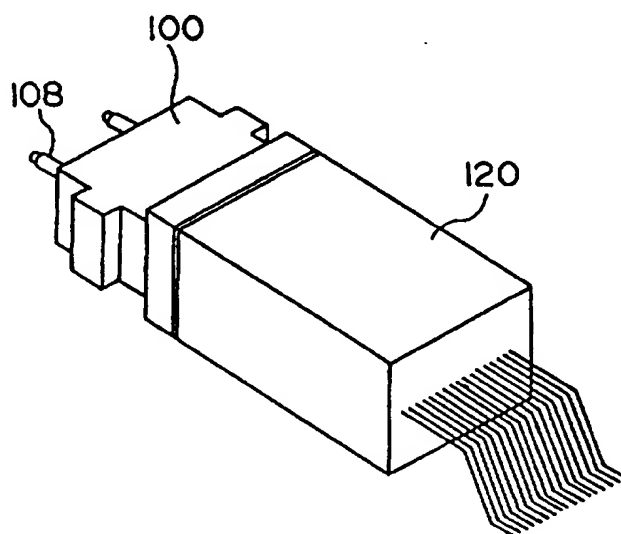


Fig.47A

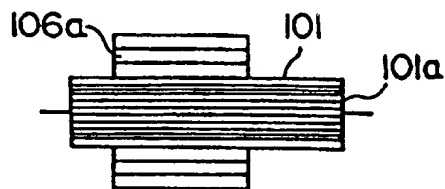


Fig.47C

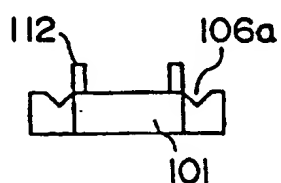


Fig.47B

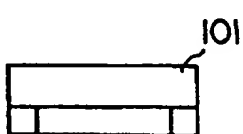


Fig.47D

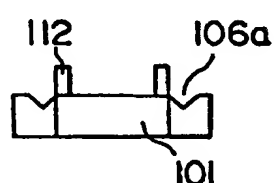


Fig. 48A

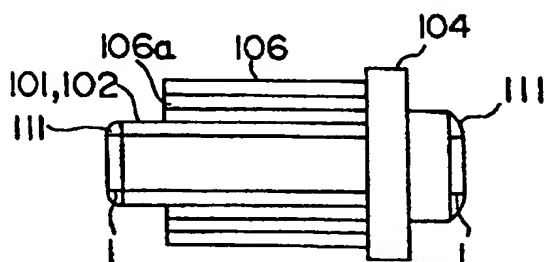


Fig.48C

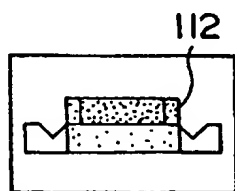


Fig.48B

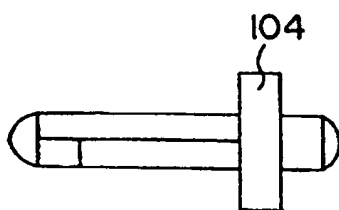


Fig.48D

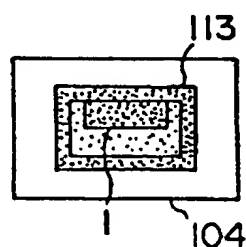


Fig.49

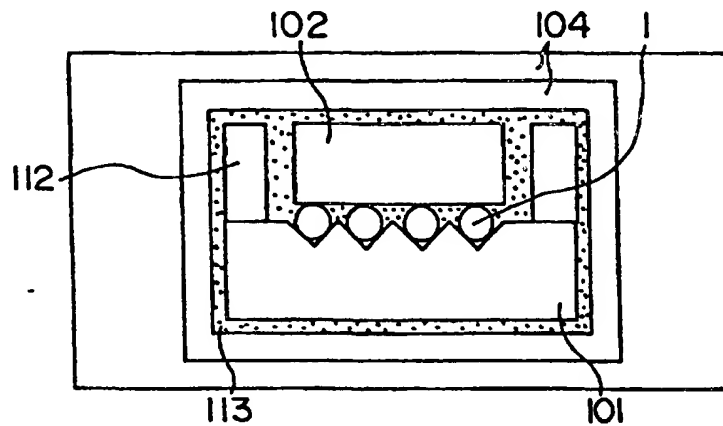


Fig. 50A

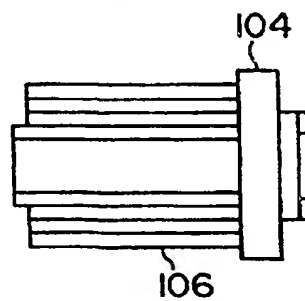


Fig.50C

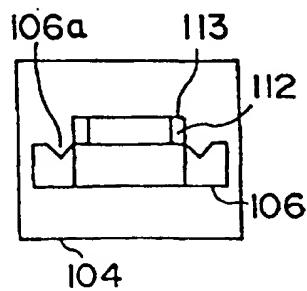


Fig.50B

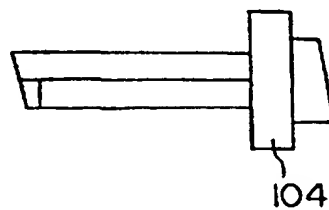


Fig.50D

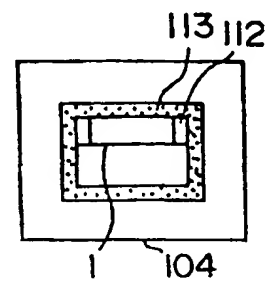


Fig. 5IA

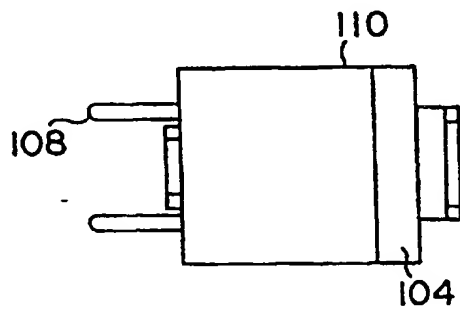


Fig. 5IE

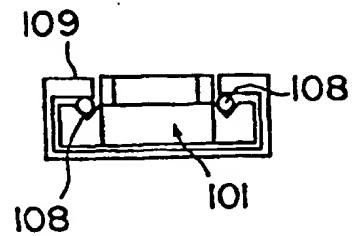


Fig. 5IC

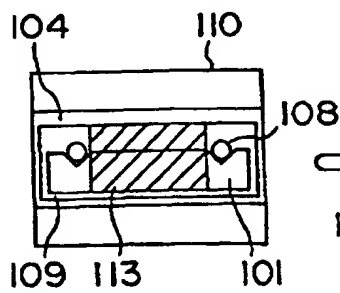


Fig. 5IB

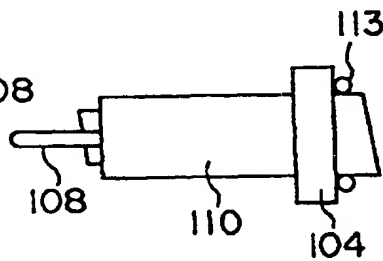


Fig. 5ID

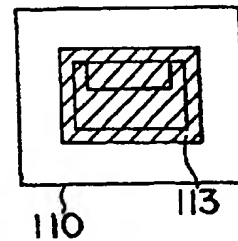


Fig.52A

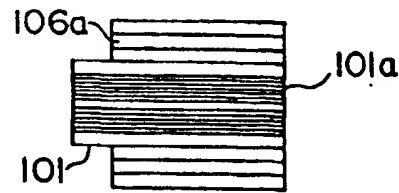


Fig.52C

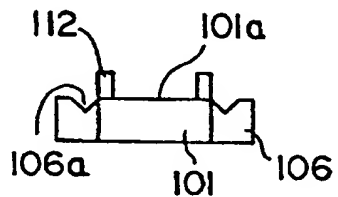


Fig.52B

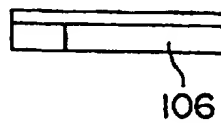


Fig.52D

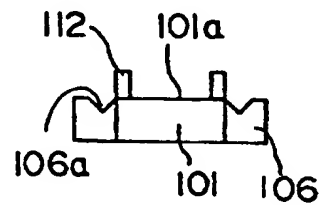


Fig.53A

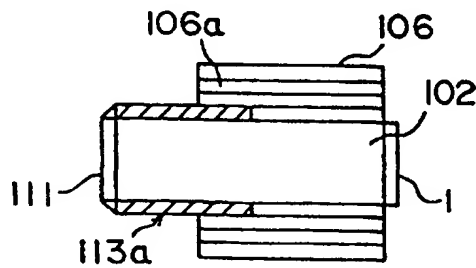


Fig.53C

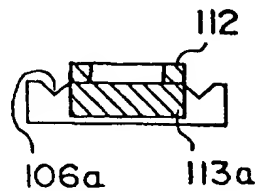


Fig.53B

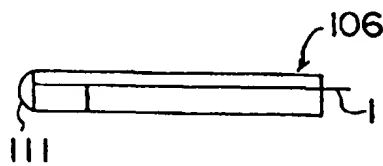


Fig. 54A

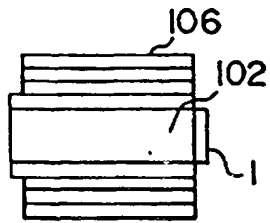


Fig. 54C

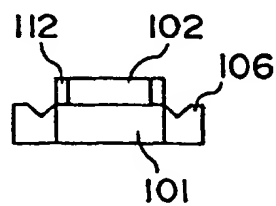


Fig. 54B

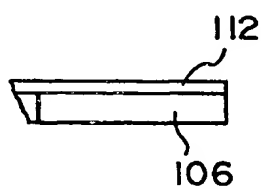


Fig. 55A

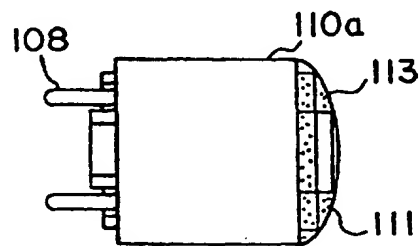


Fig. 55C

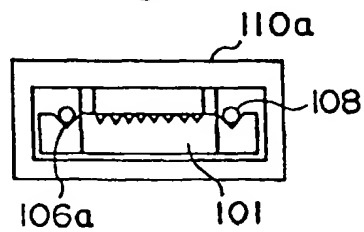


Fig. 55B

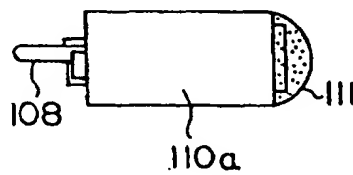


Fig. 56A

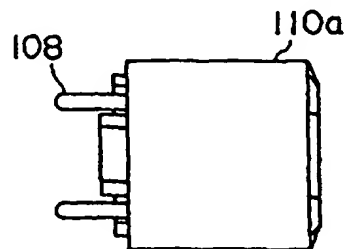


Fig. 56C

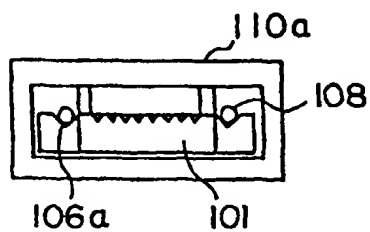


Fig. 56B

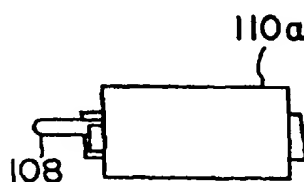


Fig. 57

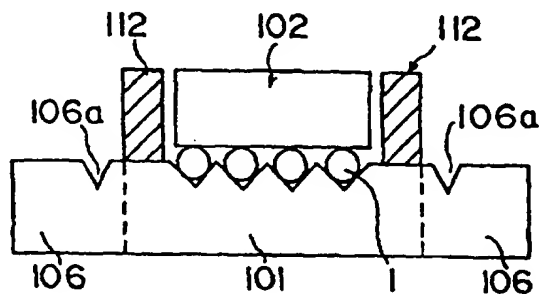


Fig. 58

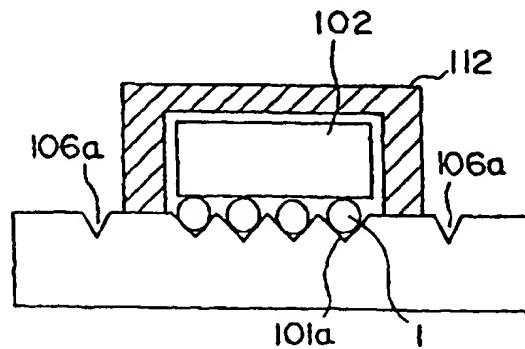


Fig. 59

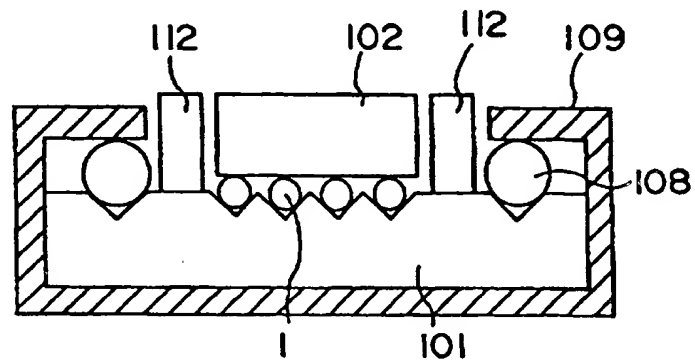


Fig. 60

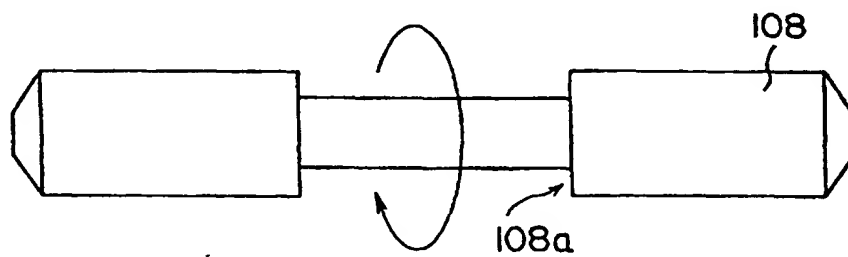


Fig. 61

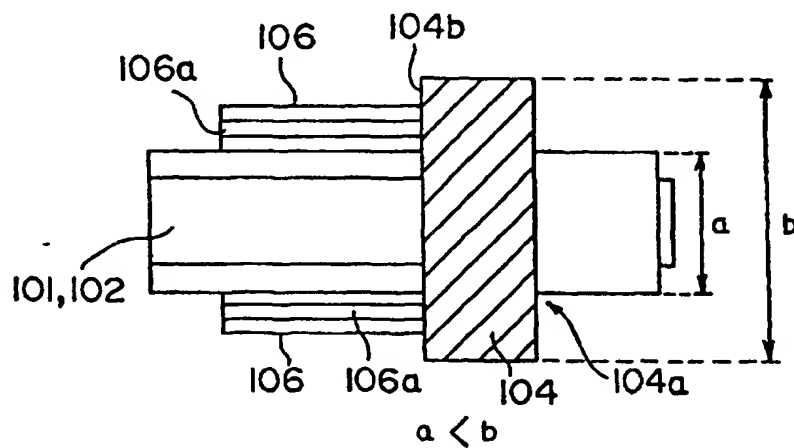


Fig. 62A

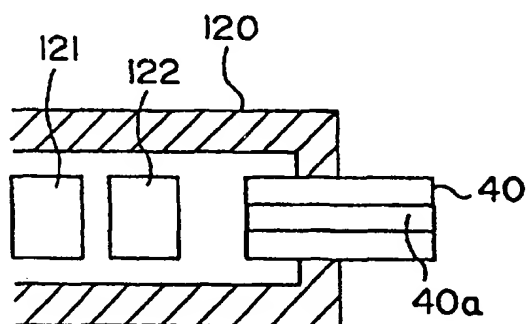


Fig. 62B

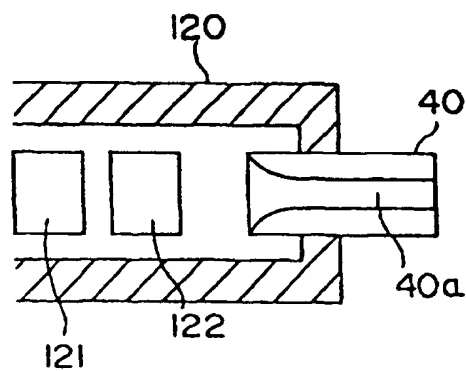


Fig. 63

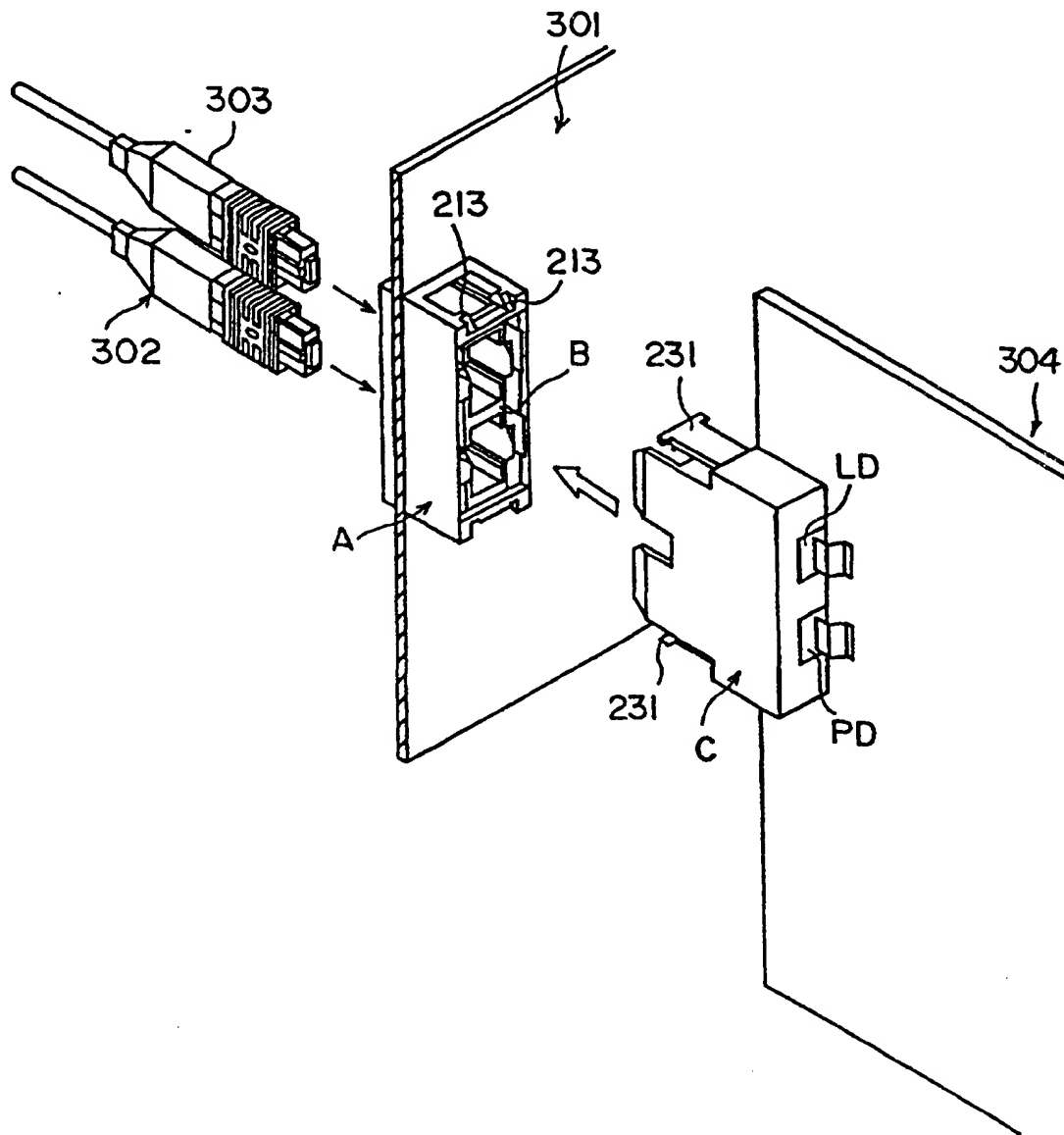
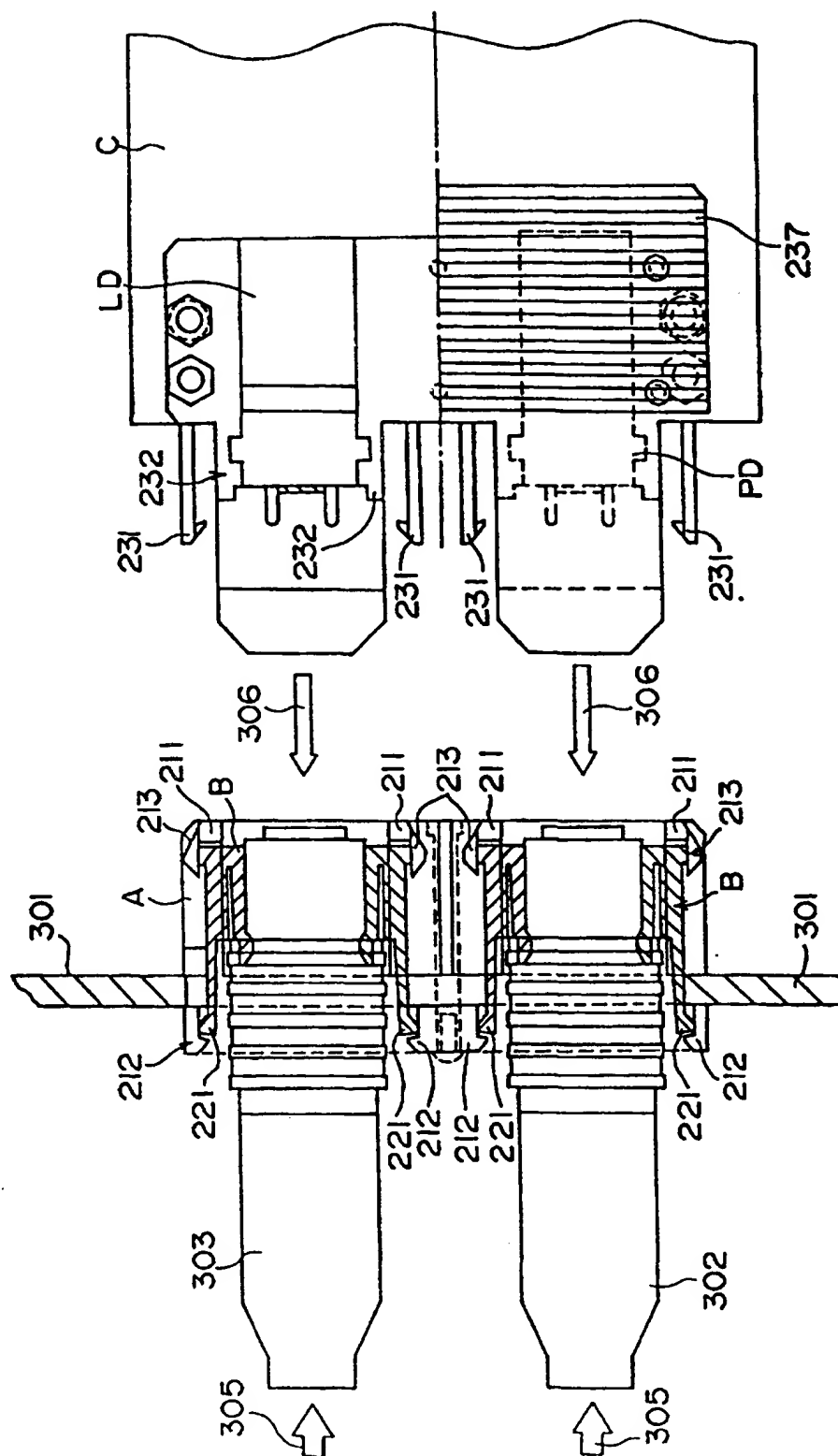


Fig. 64



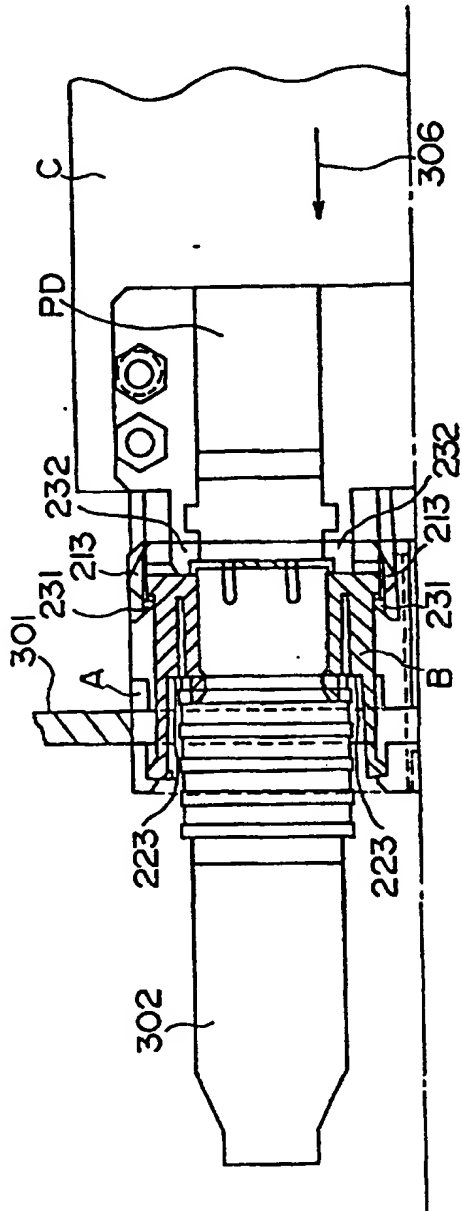


Fig. 65

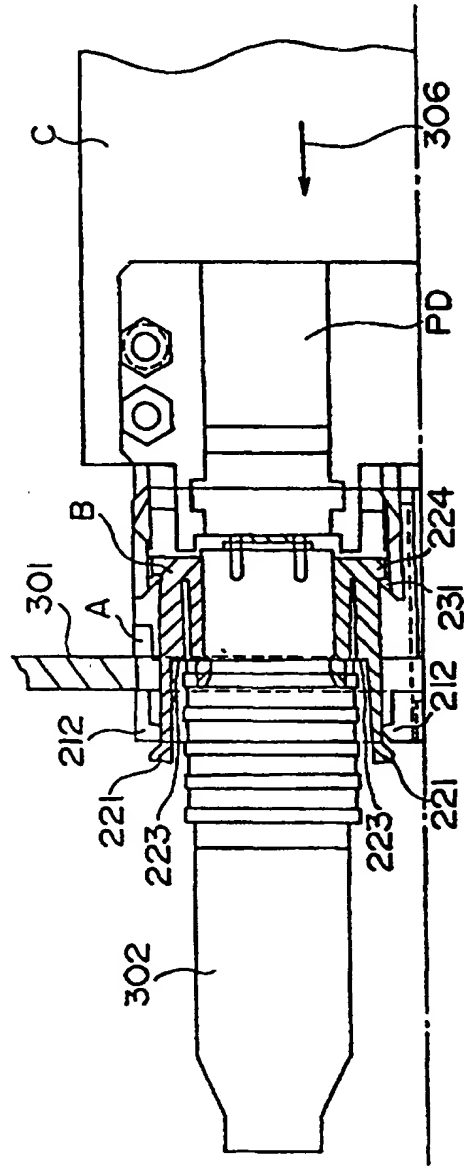


Fig. 66

Fig. 67

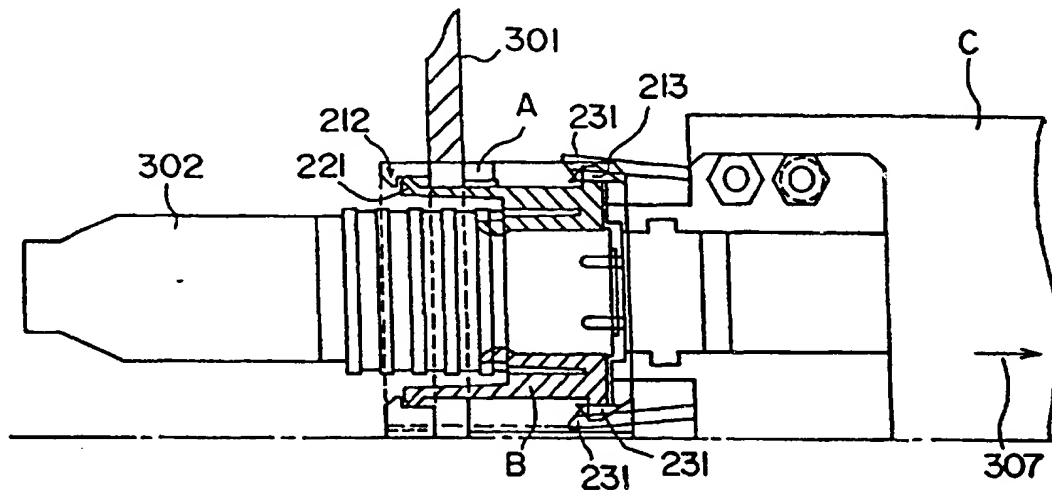


Fig. 68

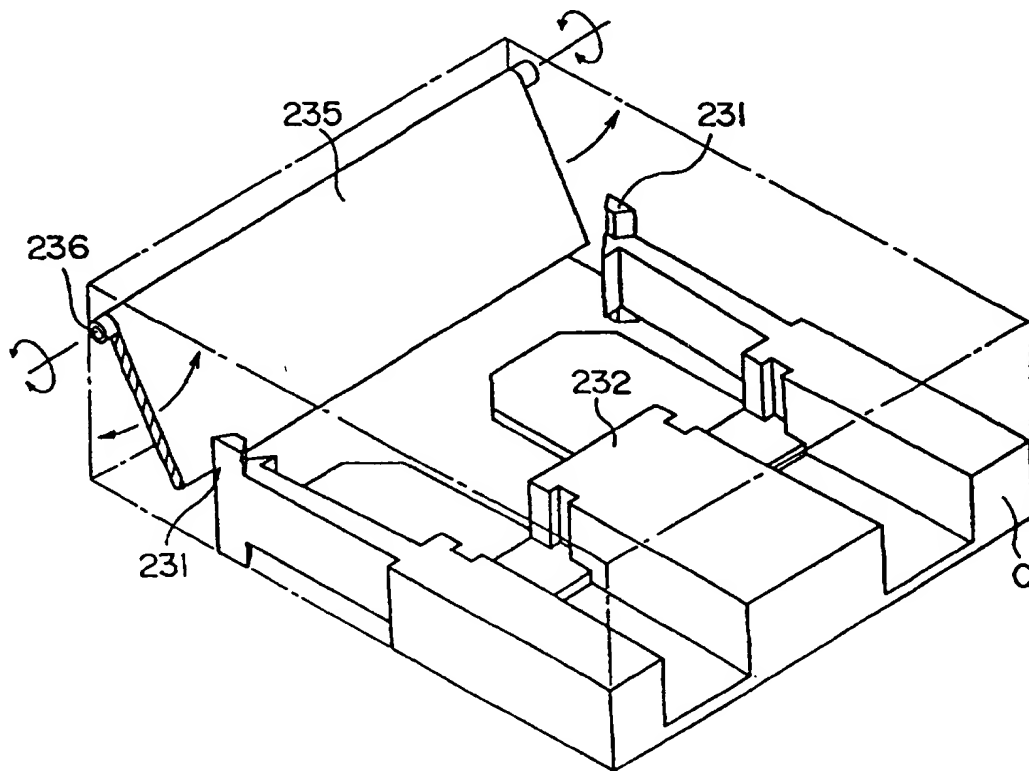


Fig. 69

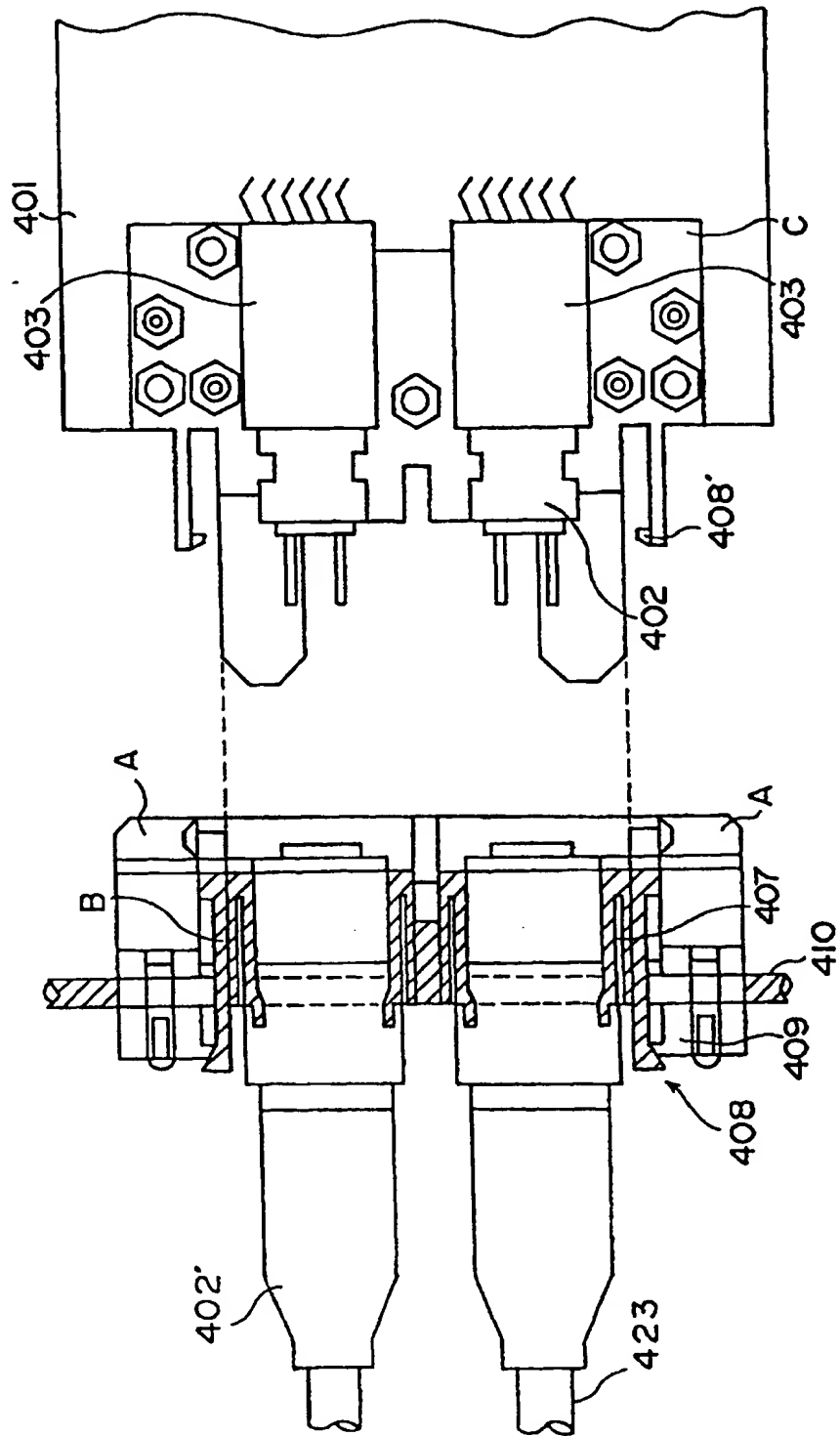


Fig.70A

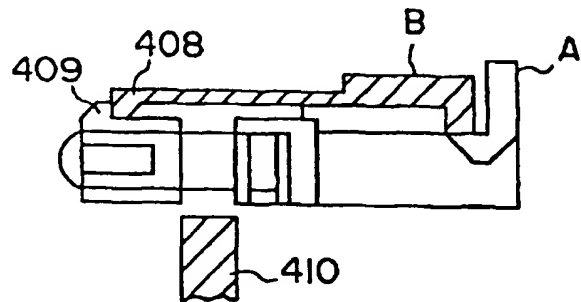


Fig.70B

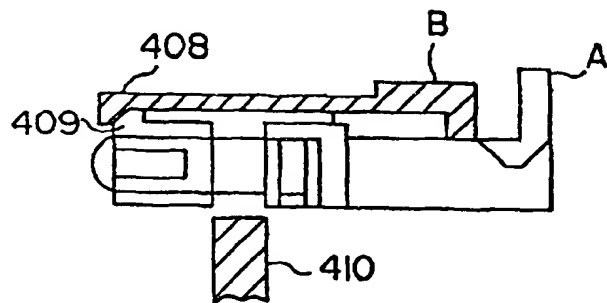


Fig.70C

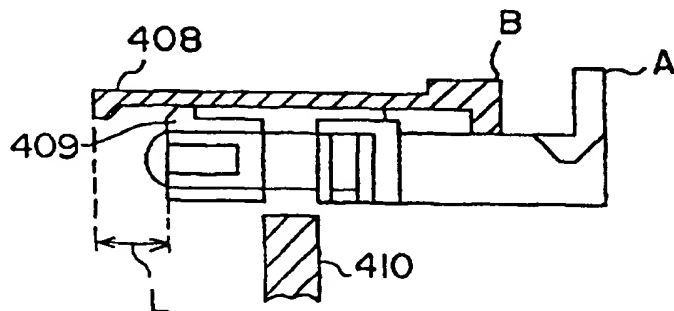


Fig. 71

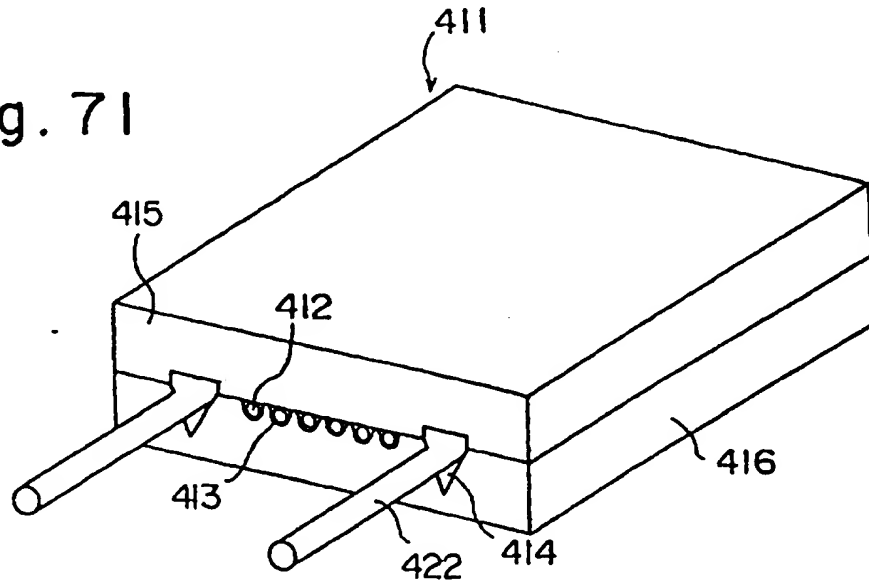


Fig. 72

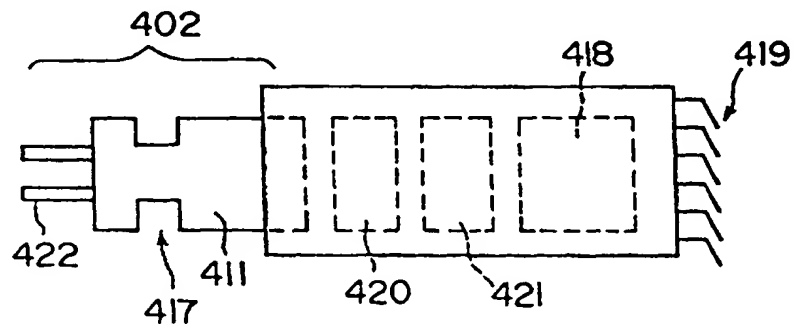


Fig. 73

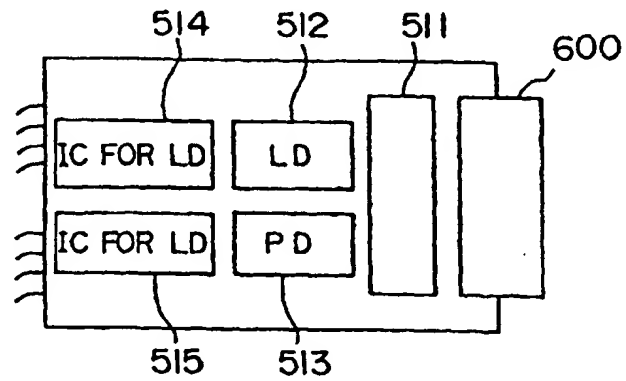


Fig. 74

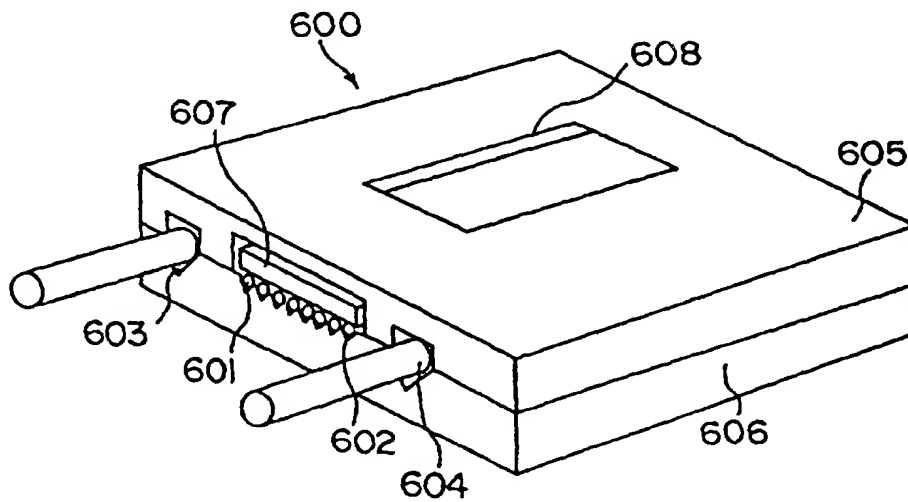


Fig. 75

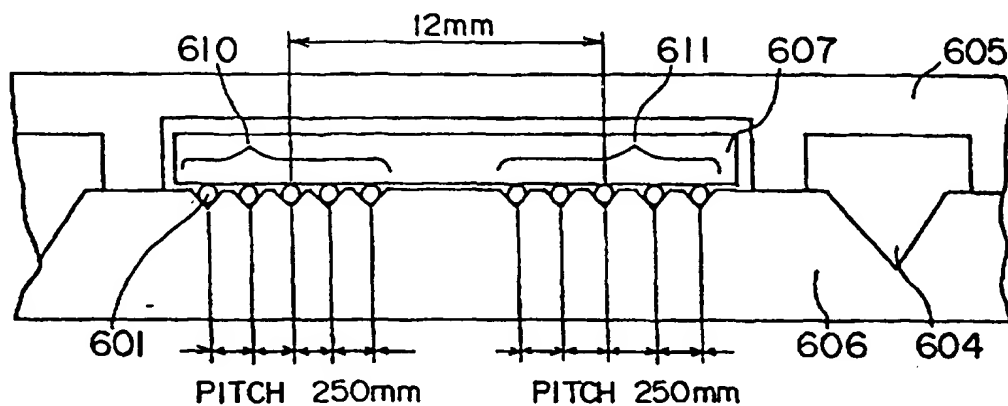


Fig. 76A



Fig. 76B

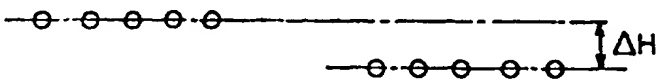


Fig. 76C

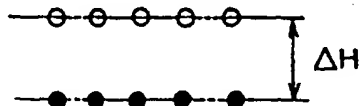


Fig. 76D

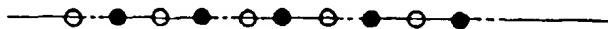


Fig. 77

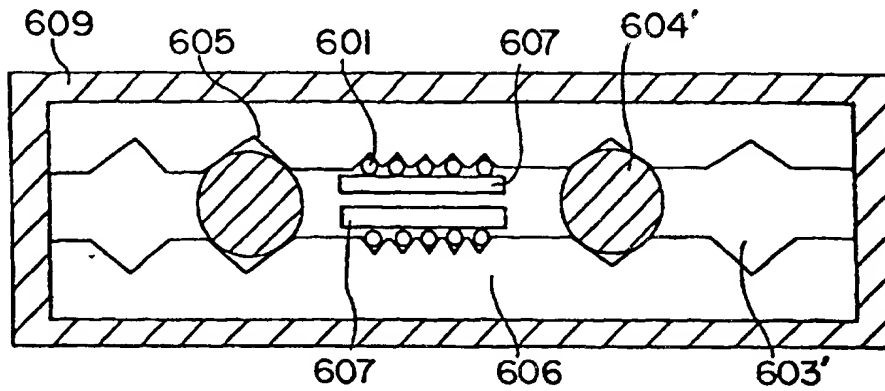


Fig. 78A

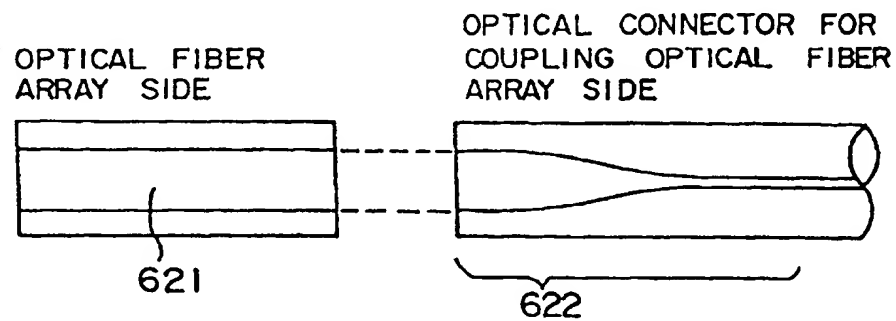


Fig. 78B

